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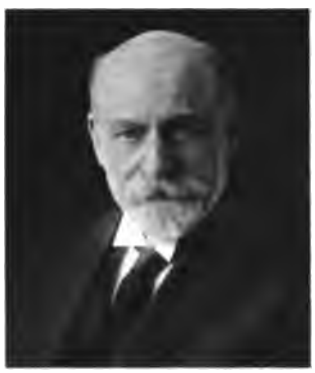

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Vol. X, 1877.

Part 1.—Annual report for 1876. Geological notes on the Great Indian Desert between Sind and Rajputana. On the occurrence of the cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. On Estheria in the Gondwana formation. Notices of new and other vertebrata from Indian tertiary and secondary rocks. Description of a new Emydine from the upper tertiaries of the Northern Punjab. Observations on underground temperature.

Part 2.—On the rocks of the Lower Godavari. On the 'Atgarh Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Arvali series in North-eastern Rajputana. Borings for coal in India. On the geology of India.

Part 3.—On the tertiary zone and underlying rocks in the North-west Punjab. On fossil floras in India. On the occurrence of erratics in the Potwar. On recent coal explorations in the Darjiling district. Limestones in the neighbourhood of Barakar. On some forms of blowing-machine used by the smiths of Upper Assam. Analyses of Raniganj coals.

Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Eryon Comp. Barrovensis,' McCoy, from the Sripermatur group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the North-west Punjab. Note on the genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks, &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a trip over the Milam Pass, Kumaun. The mud volcanoes of Ramri and Cheduba. On the mineral resources of Ramri, Cheduba, and the adjacent islands.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOL. XXXII, PART 1.

RECENT ARTESIAN EXPERIMENTS IN INDIA. *By* E. VREDENBURG, A.R.C.S., *Officiating Deputy Superintendent, Geological Survey of India.*

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CONTENTS.

CHAPTER I.— PAGE

General Consideration 1

CHAPTER II.—DETAILED ACCOUNTS OF SOME RECENT EXPERIMENTS.—

1. Baluchistan 24
2. The Gangetic alluvium 28
3. Other Alluvial areas 49
4. Gujárát 69
5. Borings in other tertiary rocks 75
6. The Gondwanas 76
7. The Vindhyans 82
8. The Deccan Trap 84
9. Other rocks 87
10. Conclusion 88

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RECENT ARTESIAN EXPERIMENTS IN INDIA.

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CHAPTER I.

GENERAL CONSIDERATION.

During the century which is now ending, the question of a water-supply from artesian sources has from time to time attracted the attention both of the Government and of the public in India. In the year 1881 Mr. Medlicott summed up all the information available up to that date in a Memoir which was published in the Records of the Government of India,[1] and in those of the Geological Survey.[2]

Origin of water-supply.

The principle of artesian wells is now so generally understood and has been so often described that there is no need to enter into any detailed discussion

[1] Reports on Artesian Borings in India. Selections from the Records of the Government of India, Home, Revenue and Agricultural Department. No. CLXXVIII, Calcutta, 1881.

[2] Artesian Borings in India. Rec. Geol. Surv. Ind., Vol. XIV, pp. 205-238.

of the conditions essential to their occurrence. Briefly considered they depend upon the following phenomena. The water that is poured over the land in the shape of rain is disposed of in three ways: part of it is returned to the atmosphere by evaporation; part of it runs over the surface to form rivers flowing towards the sea or towards some inland drainage basin; while the remainder sinks into the ground. It is from this subterranean source that artesian wells and also ordinary shallow wells derive their supply.

That portion which soaks into the ground usually keeps the soil and rocks moist up to a certain distance from the surface. Beyond a certain depth, which varies locally according to the amount of rainfall and the nature of the rocks, this moisture gives place to complete saturation. The water thus occupying the interstices of the rocks forms an underground reservoir, the amount stored away depending on the porosity of the rock. When the interstices take up a considerable proportion of the volume occupied by the rock, the amount of water that can be stored is proportionately great. The rock is then said to be "porous" or "permeable," while, if the opposite conditions prevail, the rock is more or less "impermeable." The degree of coarseness of texture is also to be considered, for if the interstices are very small, the retarding effects of friction and capillarity come into greater play, and in this way certain fine-grained rocks, such as clay, act as highly impermeable strata notwithstanding the fact that they can absorb a certain amount of water. On the other hand it may also happen that rocks of an impermeable texture may act as porous masses owing to their fissured or cavernous conditions. Sandstones and conglomerates constitute the most usual instances of porous formations. Some kinds of non-indurated calcareous rocks, such as chalk, are also fairly permeable. Clay is a well-known example of an impermeable medium, while the same is usually the case with crystalline sandstone or "quartzite," crystalline limestone, and the generality of igneous and metamorphic

the one at which it was tapped, as soon as the impermeable layer is pierced; and if there be a sufficient difference in the altitudes of the surface at the well and at the source of supply, or fountain-head, the water may rise higher than the level of permanent saturation of the neighbourhood of the well, and may even overflow at the surface. Only to such flowing wells is the name "artesian" applied by certain authors, while according to others, the name should be given to all wells in which water rises to a higher level than that at which it was tapped. It is this latter view which was eventually taken by Mr. Medlicott: "Partial artesian action is always possible when percolation along the planes of bedding is much more easy than across them, and this seems to be a general character of stratification independently of any visible impervious beds."[1] The exclusion of all but flowing wells from the class of artesian wells is a somewhat artificial restriction. Two neighbouring wells may tap the same underground reservoir, and owing to a difference of a few feet in the altitude of the places at which they have been sunk, one of them may overflow and not the other, although all the other conditions are just the same. Moreover, a non-flowing well may, by means of pumping, prove of just as much practical utility as a flowing one, if the supply is abundant. A flowing well, on the other hand, may be of very little use if it gives a small delivery for a given diameter of the bore: the Lucknow boring struck at a depth of 1,189 feet a sheet of water under sufficient pressure to overflow at the surface; but the delivery was insignificant.

Uncertainty of nomenclature.

The conditions of artesian reservoirs are very completely discussed in a treatise by Prof. Chamberlin published by the Geological Survey of the United States.[2] Artesian reservoirs were divided by him into "perfect

Perfect and imperfect reservoirs.

[1] Rec. Geol. Surv. Ind., Vol. XVI, p. 206.

[2] "The requisite and qualifying conditions of Artesian Wells," by T. C. Chamberlin. Fifth Annual Report of the United States Geological Survey, pp. 125-173.

rocks, which can only act as permeable masses when they are exceptionally fissured.

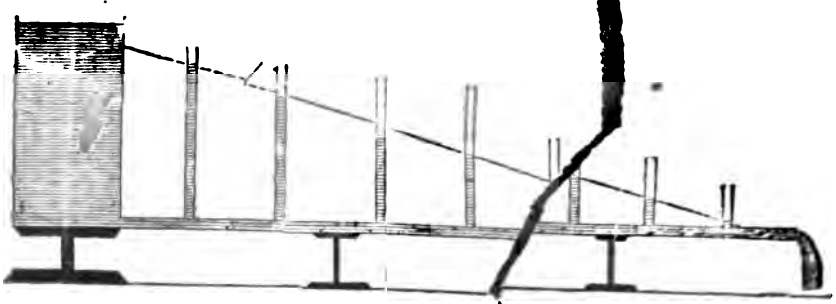
Ground-water.

These underground reservoirs formed by the water contained in porous rocks may be of two sorts. The upper surface of the underground reservoir may be in direct communication with the atmosphere through the pores of the superincumbent unsaturated rock. The reservoir is then said to consist of "ground-water" or "subsoil-water." If a shaft be sunk so as to penetrate the soil deeper than the surface level of this underground reservoir, water will percolate and fill the cavity up to that level. These are ordinary percolation wells or surface wells.

Artesian conditions.

But the underground water is not always in direct communication with the atmosphere immediately above it. We know that the composition of that part of the earth nearest the surface, the "earth's crust," which is accessible to observation, is far from being homogeneous. The rock nearest the surface at one particular point may be of a highly impermeable nature, and it may extend to a depth far greater than that of the normal level of permanent saturation. Supposing there be a porous layer beneath this impermeable one, it cannot, however highly porous, receive water from the surface directly above it, because of the intervening stratum opposing itself to percolation from above. Yet, if this porous layer extends laterally to a greater distance than the overlying impermeable one, it must come into communication with the surface at some other more or less remote point. In this way it can obtain a supply of water, and if, at the place where it receives the supply, the permanent level of saturation stands at a higher altitude than the bottom of the impermeable rock that overlies it elsewhere, the porous layer may be enclosed by impermeable rocks in such a way that the water, at the place first considered, not only exerts a pressure downwards but also presses upwards on the lower surface of the bed above it. If a shaft be sunk at that place, the water will rise to a point higher than

reservoirs" and "imperfect reservoirs." In a "p erfect reservoir" the water has no outlet at a lower level than the artificial one provided by the well. In an "imperfect reservoir" th e water possesses a natural escape at a lower altitude than the well. Yet there may still be a tendency to rise owing to the resistanc e opposed by friction along the underground channel leading to th e natural outlet. Such a condition is represented in Mr. Medlic ott's experiments illustrated in the Report already referred to. The fo llowing diagram which has been several times reproduced from Da niell's Text-book of the Principles of Physics in works dealing with e the present subject, gives a better idea of the facts than any descr ption :—



Some of the artesian reservoirs that have given the most brilliant results are of the nature of "imperfect reservoirs." The Dakota sandstone, a cretaceous rock in North America, may be quoted as an example.

In the report just referred to, Mr. Medlicott also pointed out that artesian conditions are generally very different from the exceptionally favourable conditions that hold good in the typical

examples of the London or Paris basins, which are termed "basins of disturbance" in contradistinction to "basins of original deposition." He brought to notice the fact that the structure favourable to artesian action might be caused either by subsequent tilting of strata that were originally horizontal, or else that the same action might take place in undisturbed strata that have been deposited in an inclined position, as is the case of the strata occupying alluvial plains. Sedimentary rocks may be, for the purposes of the present case, divided into two principal sections: there are, first, those ancient rocks which form such a large proportion of the earth's crust, and which geologists usually classify as palæozoic, mesozoic (secondary) and tertiary. These consist of alternating strata of varying thickness, often remarkable for the small amount of variation which they exhibit over considerable areas. They have usually been deposited upon the floor of the sea at some distance from the coast, and their distribution by marine agency has resulted in their great constancy over wide areas. Owing to changes in the relative level of land and sea, or to a folding or corrugation of the originally flat surface, these strata have come to constitute dry land and may even rise into high mountains. It is the inclined position thus assumed which often allows the formation of more or less water-tight reservoirs. The other class of strata are those that have been called diluvial, quarternary, pleistocene, or post-tertiary, the two latter terms being more commonly in use. They are newer than the strata of the first category, and consequently they rest upon them when both exist together in the same region. They merge insensibly into the alluvial deposits whose formation continues over the land at the present day. As these recent deposits, they are generally land formations in a sense of being of marine origin as in the case of the majority of the older strata grouped in the first category. They often imply, though not always, a considerable horizontal surface, but they never attain the thickness frequently exhibited

Basins of disturbance and of original deposition.

by similar strata, and they further differ from them by having a well-marked original slope of deposition. Their composition varies a great deal from place to place, and the irregularity thus produced may be favourable to the production of artesian conditions. Volcanic formations accumulated on land are comparable to these alluvial formations in their consisting also of strata of varying permeability deposited in an inclined position. As to the floor of igneous and metamorphic rocks which carries the strata of either category, it is practically impermeable. Occasionally it has been known to yield a somewhat

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L. XVI, pp. 203-209.

it has the disadvantage of leaving outside of any well-defined category all those non-flowing wells which nevertheless are not ordinary percolation wells, but which derive their supply from an underground reservoir of water under pressure. At the same time, adopting Mr. Medlicott's definition of artesian action as the tendency of water to percolate more easily along the planes of stratification than across them, the separation from an ordinary percolation well is, especially for practical purposes, not always very distinct. The "spring" wells" of the Gangetic alluvium, and some very similar ones in Gujárát, are instances of this. The alluvium of these regions contains thick beds of impervious clay known as "mota" in the North-West Provinces. These beds may occur at a depth coinciding with the level of permanent saturation, or else ten, twenty feet or more beneath it. When such a clay-bed occurs at an accessible depth at some locality where a well is needed, the well is first sunk up to the surface of this clay-bed. A narrow shaft is then excavated into the clay, and when the clay-bed is pierced, water charged with sand rushes upwards with such violence that the workmen may have barely time to escape. Captain Clibborn has given a most interesting account of such wells in a treatise on well-irrigation in the Gangetic plain, in which their peculiar action is fully explained.[1] Briefly stated, it is thus. The stratum of indurated clay that supports the well may not, and in most cases does not, extend laterally to any great distance. As therefore the water below the clay-bed is in free communication round the edges of this impervious stratum with that

"Spring-wells" of the Gangetic alluvium.

[illegible] the pressure underneath the clay stratum depends merely
but they [illegible] below the level of saturation of the ground directly
(6) [illegible] the well is sunk as far as the clay-bed, the water
[illegible] permeable sands above the clay is prevented by
[illegible] percolating into the shaft. What may have

[1] [illegible]ion in the North-Western Provinces and Oudh, by Captain [illegible]83.

collected is baled out in order that the work of sinking the smaller tube through the clay may be proceeded with. As soon as this reaches the base of the clay, the water which was under hydrostatic pressure proportional to its depth beneath the level of saturation, gushes into the well which it fills up to that level. At first the water which flows into the well is charged with sand, and thus a cavity is formed in the sandy stratum beneath the lower orifice of the pipe that traverses the clay-bed. This cavity gets enlarged until the area of its internal surface becomes sufficient to allow water to percolate at such a rate as will replenish the well while in use, without the rate of flow being sufficient to disturb the sand, as the percolation is distributed over a sufficiently large area. If the bed of indurated clay is sufficiently thick it will support the weight of the masonry above this cavity without yielding. This explanation, the credit of which is given by Captain Clibborn to Mr. J. S. Beresford, accounts fully for the facts observed, and Captain Clibborn denies that there is anything at all of the nature of artesian action. Yet, as pointed out by Mr. Medlicott in a review of Captain Clibborn's Memoir,[1] the explanation, though fully satisfactory, is not incompatible with artesian action, so long as this is described as that of water with a greater tendency to flow along the planes of bedding than in a direction at right angles. Yet, it must be admitted that they differ but very little from an ordinary percolation well, their typical feature consisting in the fact that advantage is taken of certain natural conditions to obtain a well of moderate diameter in a permeable medium of very loose material without endangering the stability of the masonry and without any risk of silting. As pointed out by Captain Clibborn, an ordinary percolation well may be sunk in any sand however coarse and unconsolidated, if only its diameter be made large enough. He has also shown that where the clay strata do not exist, they could, leaving aside the question of expenditure, be replaced artificially by building the well upon a platform

[1] Rec. Geol. Surv. Ind., Vol. XVI, pp. 205-209.

of concrete placed at some distance below the level of saturation of the ground.

It is certain that these "spring wells" hardly answer to the popular idea of an artesian well, and naturally they would not be regarded as belonging to that category by those authors who restrict the use of the term to flowing wells. It may be suggested, that if the fact that a well is a flowing one be taken as essential to artesian conditions, a further restriction must be made so as to apply the name only to such flowing wells as are fed by a deep reservoir of water under considerable pressure. This restriction is necessary so as to exclude a certain class of wells which yield a copious flow, although not possessing any of the characters of an artesian well. Such are certain percolation wells so situated with respect to the topography of their neighbourhood, that, by means of a shallow artificial channel, the water which they collect can be discharged by gravitation alone. As an instance may be quoted the wells which supply water to the town of Rawalpindi. They derive their supply by percolation from some coarse alluvial gravels which occupy a longitudinal valley bordered by rocky ridges. This valley is situated at the foot of the hills, but at a greater altitude than the town, to which the supply of the wells is carried by gravitation alone. The wells which supply the city of Karachi, sunk in the gravels of a broad river-bed that never contains any water flowing at the surface, except in times of exceptional flood, are essentially of the same nature.

Water-supply of Rawalpindi.

Here, then, we have percolation with an abundant flow, while the "spring-wells" of the Gangetic alluvium might be taken as examples of artesian action without overflow. In fact, the difficulty which is often experienced as to whether a certain well should be classed as artesian or not, has led certain writers to discard the term entirely. This is perhaps a somewhat extreme view, for although the category cannot be defined within absolutely strict

limits, yet the term is useful. It is an instance of the difficulties that are always experienced in making scientific classifications: they must always be more or less artificial, and however elaborate they can never be in complete harmony with the infinite variety of nature.

From the foregoing remarks, it follows that the "spring wells" just described, differ from the typical examples in London and Paris with regard to the situation of the well, relatively to the intake area of its water-supply. Since the clay bands which form their characteristic feature are of very limited extent, it follows that the water which they contain is, properly speaking, only "ground-water," derived from the same source as the water of ordinary percolation wells, that is, from purely local rainfall. These wells illustrate examples of local artesian action within a reservoir of water which can scarcely be called an artesian reservoir. But in the case of artesian wells like those of Paris, the porous stratum forming the natural reservoir from which they derive their supply has no communication with the surface except at its outcrop many miles away.

Special characteristics of the supply from deep artesian sources.

A very important result of this structure is that the supply of the artesian well is independent of local rainfall. Owing to its greater altitude, the collecting area is usually favoured with a more abundant rainfall than the locality at which the wells are situated. If it is sufficient to cause a constant overflow from the outcrop of the water-bearing stratum, the head of water will naturally be constant, as the artificial wells usually abstract but a small portion of the water furnished to the water-bearing stratum over the entire extent of its outcrop. Moreover, a fall of the water-level at the fountain head will not cause a corresponding loss of effective head in the well, for, owing to the retardation caused by friction, the rise of water in the well is but a fraction of what it would be otherwise. Any alteration in the level of the fountain head can only affect the outflow at the well in the same diminished proportion.

Special advantages of deep artesian sources.

These well-known features of artesian action are here alluded to because it is important to keep sight of them in discussing the capabilities of artesian wells. As already pointed out, the fact of their flowing at the surface or not is not of much importance, their usefulness, from a practical point of view, depending on an abundant and constant delivery. When the water is needed to supply a town for drinking purposes, it has this further advantage that it is free from any germs of disease. It is not, however, its applicability to domestic purposes that usually attracts public attention to artesian resources, but people have generally been struck by the achievements obtained in some countries where they have supplied the needs of irrigation. In this respect, one is apt to form an exaggerated notion of their capabilities. The imagination is easily struck by such facts as the phenomenal outflow of some of the North American wells, or by the creation of artificial oases in the midst of the Sahara. But it is necessary to keep in mind how very local these effects must remain, even at their best, and the notion, sometimes entertained, that the sinking of artesian wells would in the slightest degree afford relief during Indian famines should at once be dispelled.

Efficiency of artesian resources in deserts.

It is principally in deserts that the use which it is possible to derive from artesian water is seen to its best advantage. In a desert, no cultivation can be undertaken that depends merely upon rainfall, because the annual precipitation is insignificant and precarious. Cultivation can only be practised when that scanty rainfall, concentrated and stored by natural or artificial means, is applied to irrigation. River systems may collect from a large area so much of the rainfall as escapes evaporation, and some of their stream-beds may thus carry a perennial stream. When this reaches the plains, the water may be diverted into artificial channels and devoted to irrigation. The area thus cultivated is very small compared to that over which the rain has fallen, but it is the application to a limited area of a large

proportion of the available rainfall, which renders possible agricultural operations which would be out of the question if attempted over the entire surface of the collecting area. As already pointed out, the rain water that escapes evaporation, partly flows along the surface, and partly sinks into the ground. It is this latter portion which in some instances becomes available in the shape of artesian water. Some of the recent alluvial formations peculiar to desert areas are particularly suited to the production of artesian conditions. Of late years, complete success has been achieved in the case of artesian wells sunk through such formations at Quetta, but these same reservoirs have been drawn upon since time immemorial by means of the underground channels so well known as "karez" in Baluchistan, and "kanat" in Persia, a feature which is forcibly brought to the attention of any one travelling in those regions, which would be otherwise uninhabitable. The water which supplies the underground reservoirs represents but a fraction of the amount of water that percolates into the ground, this amount itself being but a fraction of an already scanty rainfall; but compared with the supply from rivers, it has the advantage of being much less subject to variations. Such are then the capabilities and the limitations of artesian water in a desert: its yield may be locally abundant and constant enough to allow of successful irrigation, but this yield is derived from a source so scanty that under the most favourable circumstances, the area cultivated sinks into complete insignificance compared with the immensity of the surrounding desert. One of the artesian districts that have most attracted the attention of the world is that of the Oued Voir and neighbouring oases in the Algerian Sahara. According to some statistics collected in a publication issued in connection with the Paris exhibition of 1889,[1] the total yield of the wells was then 8,475 cubic feet, or 63,400 gallons per minute. The area under cultivation was not more than 4,000 acres, that is a few thousand acres amongst many thousand square miles

of desert. Viewed in this manner, the result must appear very small, yet it is here that the capabilties of artesian water are seen to their best advantage, since they render cultivation possible in a land which must remain otherwise absolutely unculturable.

With all other conditions remaining the same, there is no doubt that as the rainfall increases the amount available from artesian sources might be increased in about the same proportion. But the same proposition would not hold good with respect to the amount of land cultivated: with an annual rainfall of about five inches, desertic conditions must prevail, and if there is no river, the country must remain without cultivation except perhaps for a few small areas under irrigation from natural underground reservoirs scattered at intervals, just as in Baluchistan or in the Sahara. If we now turn our attention to other countries where the mean annual rainfall is thirty inches instead of five, the amount of water stored in underground reservoirs will also increase in the same proportion so long as their capacity is such that they do not overflow. But it is not so with the area cultivated: instead of the few acres of cultivated land being increased in the proportion of five to thirty, we are now dealing with countries where one-half, three-quarters, or more perhaps of the land is under cultivation. For, with increased humidity, agriculture no longer depends on purely local and exceptional conditions of storage and distribution, but the rainfall over any part of the area is sufficient to supply the local needs, making irrigation superfluous. In places where the rainfall is so abundant as to be sufficient even in years of minimum rainfall, artesian wells cease to be of any value as a means of irrigation. But there are some regions where, although the rainfall is generally sufficient, yet its amount is just on the limit of what is needed, and consequently, in years of minimum rainfall, the amount is below the requirements of the land. Hence, although irrigation is superfluous in ordinary seasons, some form of storage of water is necessary in order to save the country

Inefficiency of artesian resources for irrigation in humid regions.

from ruin during the exceptionally dry years which must occur at intervals,—intervals which are irregular so far as has yet been observed. These conditions prevail over very large areas in India, and wherever sufficient provision has not been made to suit the requirements of the case, it is inevitable that ruination should visit them at intervals in the shape of the terrible calamities too well known in India during famine years. The situation of the regions thus precariously situated can be recognised by examining any map that indicates the distribution of the rainfall, such as the beautiful maps published in the Statistical Atlas of India.[1] It is probably in those regions where the average amount of annual rainfall is between twenty and forty inches that the situation is most precarious. The regions most critically stuated are,—first, the countries nearest the Indian Desert, that is portions of the Punjab, of Rajputana, of the North-West Provinces, and of Gujárát; secondly, large districts in Central India and in the Central Provinces together with part of the Deccan east of the Western Ghats, forming a considerable proportion of the Bombay and Madras Presidencies, and of the States of Hyderabad and Mysore. It is only with respect to these critically placed districts that the question of a possible supply from artesian sources for irrigation purposes is of any vital interest. As already pointed out, the desert areas are safe from severe famine, because the portion which is cultivated depends on perennial supplies of water independent of annual variations in local rainfall,—whether this supply be the mighty stream of some great river like that of the Indus, which spreads over Lower Sind the rain and melted snow of an immense catchment area in the Himaláyas, or whether it be the small but constant supply of a "karez." The more humid tracts where the rainfall is more than sufficient are equally out of question in the present enquiry. But in those vast regions where the rainfall is usually only just sufficient to supply the needs of agriculture, and where recourse must be had to some means of storage so as to

[1] Statistical Atlas of India, Second Edition. Calcutta, 1895.

tide over years of deficient rainfall, the question has been asked whether the water needed is not already stored in natural artesian reservoirs. It has already been pointed out how small is the area irrigable from artesian sources in the deserts of Algeria and Baluchistan, and it has been further argued that the water available from that source could only increase at a rate comparable with an increase of rainfall, and not comparable with the concomitant increase of culturable ground. Therefore if there occurs any failure of the rainfall in a country where rainfall is depended upon for cultivation, the portion where this deficiency could be remedied by means of artesian water would be insignificant. Another argument may yet present itself: where artesian water is regularly put to contribution for irrigation purposes, the amount which is used annually must be kept within the limits of the average annual supply to the artesian reservoir. If, on the other hand, the supply is to be drawn upon only at intervals of several years, it might be asked whether it is not possible that an artesian reservoir could exist whose structure is such that it holds in store the supply of a number of years. This might be drawn upon only in times of need, allowing the reservoir to be replenished during intervening years favoured with a better rainfall. In answer to this argument, it may first be pointed out that although such natural conditions for the reservoir are possible, and in fact do exist to a certain degree in some rare instances,[1] they are not common, for they require the coincidence of quite a number of favourable circumstances, such as an unusually large intake area, a stratum unusually porous and unusually thick, and also an

[1] Major Powell attributes partly to this cause the diminution of flow which has been observed in some of the American wells since the time when they were first sunk; "..... it may happen that the stratum has capacity for the transmission of more water than is delivered to it. If the latter relations exist in the case of a perfect or nearly perfect reservoir, and that reservoir is tapped by numerous artesian wells, the initial discharge of water from the wells is greater than the permanent discharge. The wells in such a case draw upon a body of water which may have required years for its accumulation, and their conditions of permanent flow are not reached until this accumulation has been exhausted." Eleventh Annual Report of the Director of the United States Geological Survey, Part II, p. 202.

unusually regular structure, so that the bed should be available at a reasonable depth over a large area of the country. Under the best conditions possible, the intake area must be limited to the outcrop of the permeable stratum, and this must always be very small compared with the surface of country underlaid by the artesian reservoir, so that even if exceptional conditions of storage allowed the supply of several years to be expended in one season, the amount thus made available would still remain very small compared with the needs of the large area where irrigation is required. Besides, although the amount of artesian water available in India has scarcely received a fair test, yet it may be confidently affirmed that nowhere do such exceptional conditions occur as those outlined above. In the districts liable to famine in particular, there is not the slightest indication of anything of the sort. If we look to other countries for information, there is none perhaps from which such useful lessons can be derived as from the United States of North America. In no other region of the globe are artesian conditions developed in such a favourable manner, and nowhere perhaps have they been developed so systematically. From the oldest cambrian up to those glacial deposits which, in a geological sense, were deposited only yesterday, every system of strata has yielded artesian water in abundance. The capabilities of these resources with respect to irrigation have been very fully investigated, for, just like India, North America includes large portions in which the rainfall is insufficient or only just sufficient to provide for the needs of agriculturists. Major J. W. Powell, the late Director of the United States Geological Survey, in his "Statement before the Committee on Irrigation of the House of Representatives," in 1890 has fully examined all the aspects of the question. His report, the outcome of many years of studies specially devoted to these matters, deals with the question of irrigation considered from a theoretical, practical, and legislative point of view.[1] In this work

Examples from North America.

[1] "The Arid Lands." Eleventh Annual Report of the Director of the United States Geological Survey. Part II, Irrigation, pp. 203-289.

Major Powell pronounces himself most unhesitatingly on the subject of the limited capabilities of artesian supplies, even with respect to such exceptional artesian reservoirs as those underlying the Great Plains, particularly the "Dakota sandstone," a rock of cretaceous age, whose permeability, regularity of stratigraphical structure, favourably situated outcrop, and immense extension make it probably difficult to match elsewhere. If such an exceptionally situated reservoir can only warrant very limited expectations, it would be unwise to build any hopes upon the Indian artesian reservoirs which can only be comparatively unimportant, and whose very existence is in many cases a matter of serious doubt. Evidently it is not to them that we must look for the serious problem of making up for the deficiency of water in years of minimum rainfall in the regions at present considered. This problem is all the more important because, if the calamity which overtakes those regions in years of drought could be avoided or at least considerably mitigated, their fertility in ordinary years is so great that they would be amongst the richest, if not actually the richest, provinces in India. With adequate means of providing irrigation during unfavourable seasons, even if only just enough to save the farmers and their stock from actual disaster, these regions where the rainfall is only just sufficient would be amongst the best situated from an agricultural point of view. To quote Major Powell's words, in the work just referred to: "Whenever in any district of country, there is just sufficient rainfall and no more, that is the best condition for that agriculture which is dependent upon rainfall. Any increase above that is injurious.....What then becomes necessary is to supply additional water in seasons of drought, so there may not be a time when disaster comes to the farmer. To furnish the water necessary for these disastrous years, we have to furnish a smaller amount than in other [*i.e.*, drier] regions of country.

..... Something can be obtained from artesian wells, but not a very great amount ..... They have been bored at different places

in the world and used for irrigation whenever they could be used, and it bears out the statement I make that the supply from artesian sources is always limited, is always very small, and that no great area can be irrigated thereby. If all the artesian wells in the world that are used for irrigation were assembled in one county of Dakota they would not irrigate that county.[1]"

Since, therefore, the supply from artesian reservoirs is at best local and inadequate, we must look to some different source to provide a storage of water that will apply to the whole area concerned. This store generally exists without going to such inconveniently great depths as is often the case with artesian water: it is the reservoir formed by "ground-water," or "sub-soil-water" all over the surface of the land. All over India this resource is made available through innumerable shallow wells. As pointed out in a previous paragraph, it is somewhat a matter of personal taste whether some of these wells should be called "artesian" or not, but they are to all practical purposes shallow percolation wells, and the reservoir from which they draw their supply could not properly be called artesian, however much the name might be applicable to individual wells. According to experts there is not much room for improvement either in the mode of construction or in the economical working of shallow wells as practised in India. But the system could be considerably developed, more perhaps by private enterprise than by the agency of Government, and it is, I believe, a well recognised principle that the farmers should be given every encouragement to construct new wells. Years of minimum rainfall ought to be particularly suited to this work, as it is easy to sink the wells to a good depth below the average level of saturation of the ground. A great deal was accomplished in this line during the last abnormally dry season of 1899-1900: a great many new wells have been sunk, and many old ones deepened.

Irrigation from shallow wells.

[1] *Loc. cit.*, pp. 259-260.

There are many places topographically so situated that wells provide the only available means of irrigation. But wherever feasible, irrigation from artificial canals deriving their supply from the perennial flow of natural river channels, or from artificial reservoirs will enhance the value of the land considerably more than irrigation from wells can do. This method, however, does not come under the scope of private enterprise, but can only be accomplished as an outcome of well-matured schemes of such vast proportions as can only be dealt with by Government. In this line India has nothing to learn from other countries, and her canals and her "tanks" have long commanded the admiration of the engineering world, ranking as models to be imitated wherever similar works are undertaken. It is, no doubt, to the extension of this system of irrigation from canals and to its thoroughly systematic application that we must look forward to the development of the agricultural possibilities of the country to their utmost degree of efficiency, and for the complete disappearance of those dire calamities which must keep recurring at fated intervals, so long as India is not adequately provided for against the difficulties caused by occasional periods of deficient rainfall. If artesian reservoirs were of any great utility in averting these disasters, it would seem strange indeed that their resources should have been neglected by a body of men of such ability as are found in the Irrigation branch of the Public Works Department. The explanation of that apparent neglect is, that such a resource does not really exist. Much has been done already in the way of reservoir and canal construction in districts liable to occasional drought. There remains certainly plenty to be done, for these works have not been developed to the same extent as in regions of permanently deficient rainfall where they are much more remunerative owing to their being constantly needed. The canals that are built in districts where the rainfall is amply sufficient in all but years of minimum rainfall do not seem at first sight to be remunerative, since they are

Irrigation from canals.

merely of the nature of protective works, and will probably often remain idle during periods of several years. Yet, the additional value which increased security against disaster confers upon the land must in the long run amply repay the capital expended on such undertakings. Of course, the work must eventually be carried out on a gigantic scale, and is one that even the wealthiest Government cannot perform in one day; but since the ultimate source upon which all agriculture depends is the rainfall, the most economical distribution of that rainfall must eventually become the means of obtaining the most remunerative condition of agriculture. All that has been done so far in India, has been along those lines, and when the work is completed, India will find herself able to provide amply for a much more numerous population than she supports at present, without any risk of periodical starvation, and without having recourse to such desperate palliatives as emigration and other extreme measures which have to be resorted to as a remedy for the evil as it exists at present. As to artesian irrigation which is every now and then advocated as a remedy by well-meaning persons, I have endeavoured to show that by following the question to its ultimate conclusions, we find that they must have been deluded by the deceptive appearance of exceptional occurrences, and it is well to be guarded against such proposals, and not waste upon a matter, which is only of secondary importance, energies that can find better employment elsewhere.

The foregoing remarks apply only to those areas where in all but exceptional years the rainfall is sufficient for agricultural purposes. In more arid regions, agriculture depending on local rainfall alone becomes so precarious that it is not attempted. Cultivation is only undertaken where rendered possible by irrigation, and such regions do not undergo the risk of severe famine. Artesian reservoirs are of course locally of the greatest utility wherever they can provide the necessary means of irrigation; but those regions do not present problems of such urgent character and vital importance

as the provinces where occasional failure of rain can bring about appalling disasters. To a still greater extent is this the case with actual deserts, where it may happen, it is true, that the only existing cultivation is from artesian sources, but such countries can only support the lives of some hundreds of men, not of millions like those whose unfortunately precarious condition has just been discussed.

Artesian resources in regions of abundant rainfall.

In those regions, on the other hand, where rainfall is always abundant, artesian reservoirs lose all importance as sources of irrigation, but may still be of great use in secondary though by no means unimportant questions, such as a supply for manufacturing or for drinking purposes. Thus confined within reasonable limits, the question of artesian supply is of the greatest interest, and is fully justified in attracting the attention of private enterprise or of public bodies such as municipalities.

Present state of the question.

It cannot be said that very much has been done in this line in India, and it is doubtful how much can be done. It may be safely asserted that throughout the length and breadth of India there is no artesian reservoir comparable to the Dakota sandstone of North America, or the regularly disposed basins of London and Paris. This has been clearly recognised since the day when the main features of the geological map were delineated. But the Geological Survey with its small staff of Officers has not yet been equal to the task of carrying out a detailed examination of that immense area to such a degree of minuteness as would allow of a definite opinion on the possible resources of underground reservoirs, whose performance might be small perhaps as compared with the examples just quoted from Europe and America, but which yet might prove very useful and welcome for local needs. Not only are there many portions of India proper which are "terræ incognitæ" in a geological sense, but enormous areas have been thrown open to geological observation

in Burma and in Baluchistan which still further increase the vastness of the task. Consequently, the parts of the map that have been submitted to detailed examination are very few, as the time necessary for work of that kind can seldom be spared except for some special object like the detailed survey of a small area occupied by a coal-field. Under the circumstances, the minute examination necessary to decide these questions is quite out of the question. The delineation on the map of the areas of metamorphic rocks at once excludes certain portions from the range of research since artesian water can scarcely be expected from them. But if a geological map of India be examined, it will be noticed that an enormous area of the Peninsula is occupied by a volcanic formation known as the "Deccan trap." Practically the whole of that area is unsurveyed: we know next to nothing of that immense formation, but the mere boundary of the tract which it occupies. As to its capacity as a water-bearing formation, little is known and great differences of opinion exist. The map also shows a large area occupied by the "Vindhyan" rocks. These have received more attention than the "Deccan trap," but still in a very general manner, and very little is known regarding their behaviour as water-bearing strata. Lastly, we have scarcely any information respecting the underground structure of that immense spread of recent deposits constituting the Indo-Gangetic alluvial plain, whose strata are still in the position in which they were deposited, and no exact knowledge of which can be arrived at except from actual borings. In the opening paragraph of these notes, I mentioned that a review of the whole question as it then stood in India had been written by Mr. Medlicott in 1881. It cannot be said that the knowledge gained in the two decades that have since elapsed can allow much to be added to what he so ably discussed. Artesian problems are always so full of uncertainty that the results of actual experiment play an important part in arriving at any definite conclusions respecting subsequent trials. The experiments carried out since the publication of

Mr. Medlicott's report have not been very numerous. Most of them have been described in the publications of the Geological Survey. A short account of the most important ones is given in the following chapter.

CHAPTER II.

DETAILED ACCOUNT OF SOME RECENT EXPERIMENTS.

(1) *Baluchistan.*

The most successful borings are those of Quetta. The structure of the deposits underlying the plain of Quetta has been fully explained by Mr. Oldham in a paper published by the Government and reproduced in the Records of the Geological Survey.[1] The town of Quetta is situated in the midst of a broad plain surrounded by high ranges of hills. The streams that issue from those hills carry, in times of flood, boulders and coarse detritus which they abandon owing to the diminished gradient when they enter the plain. Owing to the scantiness of the rainfall, the plain is not scoured by streams powerful enough to remove these materials, and thus shallow cones of talus material or "alluvial fans" are formed, constituting a very characteristic feature of desert regions. They all coalesce with one another and with the talus formed by the ordinary process of disintegration, forming a broad incline, the so-called "daman" which fringes the mountain ranges in Baluchistan. At the apex of each of the shallow cones the river divides itself into a number of branches very much as it would do in a "delta." These channels are usually

Structure of recent deposits of the Quetta plain.

[1] "On the mode of occurrence and probable distribution of artesian water in the valley plains of the Quetta and Pishin District," reprinted in "Sub-recent and Recent Deposits of the valley plains of Quetta, Pishin, and the Dasht-i-Bedaolat; with appendices on the Chamans of Quetta, and the Artesian Water Supply of Quetta and Pishin." Rec. Geol. Surv. Ind., Vol. XXV, pp. 36-53.

dry, and it is only when there has been a shower that they give passage to a stream of water which bears sand and boulders if the shower has been abundant enough. The more important channels in the fan, those that are, for the time being, so situated as to collect a great amount of water, carry their burden farthest and send tongues of gravel reaching the plain. Like all rivers they are apt to shift their position, and the coarse gravels in the abandoned channels become gradually buried under the deposits of fine silt known as "loess," which are derived from the disintegration of neighbouring rocks or consist of wind-borne dust floated from afar, and which gradually get spread over the land by the slow and gentle action of rain-wash. The same process is many times repeated till the plain is occupied by a succession of irregular tongues or patches of loose permeable gravel alternating with layers of silt which are highly impermeable owing to their fine texture and argillaceous composition. The tongues of gravel decrease in coarseness as they slope towards the plain; they are entirely enclosed by the impermeable clays except at the apex of the alluvial fan where, by increasingly coarse material they all come into communication with the chaotic accumulation of boulders at the debouchure of the river from the hills. Owing to the torrential nature of the rivers and the peculiar structure of the alluvial fans, the gradients are high, so that there is a considerable difference of level between the coarse gravels at the head of the fan, and the plain over which the deposits are distributed. Thus arises a condition which is eminently suited to artesian action. The coarse nature of the deposits at the head of the slope of the "daman" favour percolation; the water gradually finds its way into the buried tongues of gravel, and the impermeable clays which enclose these gravels prevent all natural escape, thus producing an artesian reservoir which is eminently of the "perfect" type. Where these reservoirs can be tapped they are extremely useful, since by means of them it is possible to distribute to the arid soil of the plain the

relatively abundant rain that falls on the hills where it would be of no use owing to the steepness of their bare slopes.

So long as they are left to their own devices, it is not within the means of the inhabitants of these sparsely populated districts to obtain this water through artesian wells, as they do not possess suitable appliances to reach the requisite depth. But with their simple methods they can obtain the same supply by the much more laborious task of driving a horizontal gallery through the inclined beds in the lower portion of the talus. These are the works known as "karez" or "kanat" which have already been mentioned in a previous paragraph. The water is not under great pressure where the stratum containing it is penetrated by works of this kind, but the great surface of percolation in the gallery allows the collection of an abundant supply. The first attempt to tap this supply by means of a boring was made at Quetta in 1889. The experiment was eminently successful and, since then, many other borings have succeeded, while experiments of a promising nature have also been attempted in the plain of Pishin. From the irregular conformation of these deposits, the prospects of success at any particular point within the area covered by them cannot be accurately predicted. The tongues of gravel must overlap one another in a very irregular manner, and there is no means of knowing their lateral extension. At one place, a water-bearing stratum may be struck at a much smaller depth than at another, while it may also happen that the gravel may be missed entirely, which explains why some borings have been unsuccessful, though surrounded by others that have met with water-bearing strata. In fact in all artesian reservoirs like this one, consisting of recent undisturbed deposits, the only indication that can be given with any degree of accuracy is the main boundary of the area within which success is possible, but success at any particular point within that area must remain, to a great degree, a matter of chance.

The yield of a small artesian reservoir, like that of the Quetta basin, situated in a very dry region, is subject to a certain amount of variation according to differences in the amount of yearly rainfall. The flow from the karez galleries at Quetta is known to be affected to some extent by such variations, and some of them have even been known to stop flowing entirely after prolonged periods of abnormal drought.

Other localities favourably situated.

The structure of the recent alluvial deposits in the valley-plain of Quetta is by no means special to that one locality, but is common in a greater or less degree to all the talus deposits that fringe the high mountains of Baluchistan and Persia, of that arid table-land known as the plateau of Iran. At many places, the water which they contain is tapped by the karez and kanat galleries, and, no doubt, it would be available also by artesian wells. For instance, all along the mountain ranges which form the southern border of the great desert which stretches from Nushki up to the Persian Frontier, these talus deposits frequently assume enormous proportions. At a few localities far distant from one another, karez tunnels have been driven into them, and it would be worth while making an experimental boring at one of the most likely places.

Boring records of wells at Quetta.

There is not much that calls for comment in the boring records of the wells in Quetta. The deposits are too irregular to allow the identification of strata encountered in different wells. In all the borings, the same varieties of sands and clays were met with in alternating layers. The following records were published by Mr. Oldham in the report already referred to:—

SECTIONS OF BORE-HOLES AT QUETTA AND BOSTAN.

1. Well at Railway station—

120 feet loess.

20 feet gravel, underlaid by quicksand.

Discharge 20,000 gallons per hour; hydrostatic head 50 feet.

2. Well in Political Agent's compound.

115 feet loess.

8½ feet shingle with a little artesian water.

2 feet loess.

Gravel, an abundant discharge of water.

3. Well in Loco. Superintendent's compound—

92½ feet loess.

3½ feet gravel with artesian water.

4. Well in Executive Engineer's (Railway) compound—

90½ feet loess.

10 feet gravel, from which water just flowed at surface.

10 feet loess.

20 feet coarse sand and gravel, with an abundant discharge of water.

5. Well at Gymkhana—

77 feet loess.

10 feet "hard sandy stuff".

8 feet "indurated sandy lumps".

35 feet "clay with nodules".

3 feet quicksand.

12 feet hard clay.

Quicksand with water.

6 Artesian well at Bostan, as determined from specimens preserved—

10—20 feet pale yellow unctuous clay containing fine grains of silica and effervescing freely with acids. LOESS.

20—30 feet the same, but not so fine grained.

30—40 feet finer than 10—20 feet.

40—60 feet very like 20—30 feet.

60—80 feet the same with some pieces of calcareous rock (kankar).

80—90 feet same as 10—60 feet.

100 feet irregular small pebbles of pale grey limestone.

180 feet still in gravel, discharge of water 2,500 gallons per hour.

230 feet or thereabouts, entered as Siwalik clays.

(2) *The Gangetic alluvium.*

Structure of the strata.

Alternating strata of varying coarseness deposited at a gently sloping angle, and becoming generally finer-grained as the distance from the hills increases,

are characters common to all alluvial deposits. But endless variation is introduced by differences in horizontal extent, vertical depth and gradient. Thus the conditions which cause artesian flow at Quetta exist to a certain degree in all alluvial plains. Nevertheless the capacity of the reservoirs thus formed must vary greatly according to local conditions. It is natural that the immense extent of land occupied by the Indo-Gangetic alluvium should have attracted a great deal of attention from the point of view of artesian supply, but its capabilities have scarcely been tested: experiments have been so few and so incomplete that its structure is still to a great extent a matter of conjecture. Just as the upper part of the talus skirting the Baluchistan mountains consists of accumulations of boulders continuous with gradually finer gravels that dip under the fine clay deposits of the plains, so does the upper part of the alluvial talus all along the foot of the Himaláyas consist of coarse gravels forming the slope called "bhábar," the lower part of which dips under the soil of the "tarái." Mr. Medlicott argued that the gravel beds of varying degrees of coarseness that are interbedded at various depths with the clay deposits of the alluvium, must be in communication with the "bhábar" zone of gravel: here then, just as in the case of the Quetta plain deposits, leaving aside the difference in proportions, we have the requisite conditions for a very perfect artesian reservoir. Percolation acts freely in the coarse deposits of the gravel zone which absorb a considerable proportion of the rainfall, and the overflow at the upper part of the underground reservoir makes itself evident from the copious springs which issue in the zone along which the gravels dip under the clay deposits of the tarái. This line of springs indicates therefore the altitude of the fountain head of the artesian reservoir, and, by tapping that reservoir in the alluvial plain, at lower altitudes, water may be expected to overflow at the surface. In order to make the conditions of success as favourable as possible, the proposed wells should not be sunk too far south from the Himaláyas, because, with such a low gradient as that which prevails at a

distance from the hills, the retarding influence of friction must come conspicuously into play. Along the southern edge of the plains the conditions cannot be regarded as favourable, for all along the low hills that limit the alluvium in that direction, there is no slope of gravel forming an intake area comparable to the "bhábar" of the Himaláyan talus, and in the western portion of the district, in the neighbourhood of the Aravallis, the amount of rainfall is small. As to the underground reservoirs fed by the Himaláyan "bhábar" it is not probable that they stretch right across to the southern boundary of the alluvium. All these probabilities were very distinctly formulated by Mr. Medlicott in discussing the possibilities of the Indo-Gangetic alluvium. It is to the fact of their being situated too far in the midst of the alluvial formation or too near its southern limit, that he attributed the unsatisfactory results of the experiments undertaken in Calcutta in 1836 and at Bhiwani in 1877. One of the consequences of the Umballa boring carried out from 1869 to 1872 was to draw attention to the enormous thickness of the Gangetic alluvium. In order to account for the facts, it became necessary to admit that the floor upon which the Gangetic alluvium was laid down must have been subsiding simultaneously with the deposition of the strata. The depression was probably formed at the same time as the upheaval of the Himaláyas, both phenomena being the outcome of the same set of causes. It may be necessary, therefore, to bore through an enormous thickness of clay-beds similar to those met with in the Umballa boring before striking any permeable sands in communication with the coarse gravels of the "bhábar" zone. The Umballa boring was not continued beyond a depth of 701 feet, and, as an experiment therefore, it was not complete.

The Lucknow boring performed in the years 1888 to 1890 has further confirmed the fact of the enormous thickness of the alluvium, but it has also established the correctness of Mr. Medlicott's view as to the existence of deep-seated artesian water, for, between the depths of 1,189 and 1,202 feet,

The Lucknow boring.

a sheet of excellent water was tapped under sufficient pressure to cause it to overflow at the surface. The flow was not abundant, but it is possible that sands bearing a more abundant supply exist lower down. Unfortunately the boring could not be carried deeper than 1,336 feet. It was executed by Mr. Trowbridge, an engineer highly experienced in these matters, who was specially selected for this work by Messrs. Pierce and Co. of New York, one of the leading American firms that have made deep boring a speciality. It had not been anticipated that the boring would have had to be put down to such a depth entirely through unconsolidated alluvial formations. The bore-hole had to be lined throughout its entire depth, and as each size of pipe can be sunk only through a limited depth, the lining had been reduced to 3 inches diameter when it reached a depth of 1,264 feet, the greatest depth to which it was found possible to sink the pipe, although the boring had been commenced with a 12-inch pipe. The following statement contains particulars relative to the lining :—

	Size of pipe.	Length.	Depth driven.	Total depth.
1.	12 inches.	408 feet.	408 feet.	408 feet.
2.	10 „	798 „	390 „	798 „
3.	8 „	315 „	100 „	898 „
4.	6 „	1,100 „	202 „	1,100 „
5.	4 „	298 „	89 „	1,189 „
6.	3 „	246 „	77 „	1,264 „

Boring continued to 1,336 feet.

The following information was given by Mr. Trowbridge in his report to the Municipal Board of Lucknow : "From the surface down to about 400 feet, the whole soil appeared to be saturated with water, its natural level being about the same as surface water. From 400 to about 750 feet there was no appearance of water, but at that point, a bed of water-bearing sand was struck, and the water raised to within 13 feet of the surface, which is about 32 feet higher than the Gumti river when at its lowest stage. From 750 feet to 1,220 feet, occasional beds of water-bearing sand were found, which in

every instance developed a pressure sufficient to raise the water very nearly, or quite to surface, but evidently of not much volume."

"The last bed of sand found, however, extended from about 1,160 to 1,220 feet, about 13 feet of which—from 1,189 to 1,202—was a live quicksand, and contained water of sufficient pressure and volume to produce a flow over the top of the pipe at 6 feet below the surface, 26 feet above the river, amounting to about 10 gallons a minute —14,400 a day—which proved on analysis to be perfectly pure water. The quantity was not sufficient to be of practical value, and the boring was continued in search of a more abundant supply, and in order to sink the well deeper it was necessary to drive the pipe down, and that cut off and effectually stopped the flow already obtained."

The boring had been undertaken in view of providing a water-supply to the town of Lucknow. On account of the considerable interest arising from its partial success, it was intended to make another trial beginning with a much larger diameter (a 24-inch pipe) by means of which it was hoped that a depth of 2,000 feet would be reached. But it was calculated that even if the experiment were entirely successful, and a copious supply discovered, it would be necessary to bore a number of such wells, perhaps as many as ten, so as to supply the town with sufficient water, and on account of the great expense incurred in boring to such considerable depths, the scheme would have been far more expensive than that of furnishing the town with water from the Gumti river, even with all the additional expense of the plant required for raising the supply, filtering it, etc. Hence the experiment was abandoned.

The record of the Lucknow boring has been published by Mr. Oldham in the publications of the Geological Survey,[1] and is appended below.

[1] "The deep boring at Lucknow." Rec. Geol. Surv. Ind., Vol. XXIII, pp. 261-266.

Record of the Lucknow Artesian Well.

Description of soil.	Colour.	Thickness of stratum.	Total depth
Made earth, Old Fort embankment	Brown	24	24
Sandy clay	Yellowish brown	17½	41½
Kankar, mixed with clay	Bluish grey	6½	48
Sand and clay, alternate thin layers	Brown	2	50
Quicksand, micaceous	Grey	14	64
Sandy clay	Brown	2	66
Clay, with a little fine sand	Yellow	19	85
Sand, with very little clay	Grey	5	90
Quicksand, fine	Yellow	14	104
Clay	Whitish	5	109
Clay, with scattering kankar nodules	Bluish brown	7	116
Kankar	Bluish grey	6½	116½
Sandy clay	Yellow	1½	118
Kankar and clay, mixed	Bluish grey	1	119
Sandy clay	Yellowish	2	121
Sand, clean	Grey	3	124
Sandy clay	Brown	24	148
Quicksand	Grey	4	152
Silt, fine	Yellowish brown	6	158
Quicksand, fine *water 61 ft.*	Yellowish brown	5	163
Sand, with a little clay	Yellow	6	169
Clay and silt mixed	Yellow	9	178
Clay carrying abundance of nodules	Yellowish (light)	8	186
Sandy clay	Yellow	4	190
Quicksand, very fine *water 42 ft.*	Yellowish (light)	6	196

Record of the Lucknow Artesian Well—contd.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Quicksand, coarse	Grey	13	209
Clay	Whitish	6	215
Silt, fine	Brown	4	219
Sand clay, hard	Brown	7	226
Clay and sand, mixed	Yellow	7	233
Sand, free and hard	Grey	4	237
Sand, with a little clay, soft	Brown	1	238
Sand, free and hard	Grey	1	239
Sand, soft	Grey	2	241
Sand, free and medium hard	Grey	2	242
Sand, quite hard	Grey	2	244
Sand, coarse and nearly as hard as rock	Grey	2	246
Sand, medium hard	Grey	10	256
Sand, fine	Brown	6	262
Sand, medium hard	Grey	5	267
Sand, soft	Brown	4	271
Clay and silt, fine	Light yellow	4	275
Sand, coarse and very hard	Grey	2	277
Sand, do. medium hard	Grey	2	279
Sand, coarse and hard	Grey	2	281
Sand, coarse, alternate hard and soft layers	Grey	9	290
Sand, carrying abundance of nodules, hard	Grey	21	311
Sand and silt, fine	Light yellow	8	319
Sand, medium hard	Grey	3	322
Sand, very hard, coarse	Grey	9	331

Record of the Lucknow Artesian Well—contd.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Clay and silt, fine	Yellow	7	338
Sand, coarse	Grey	3	341
Sand, coarse *water 24 ft.*	Yellow	17	358
Sand, hard	Grey	2	360
Sand with a little clay, fine	Yellow	5	365
Sand, hard	Grey	4	369
Silt, fine	Brown	4	373
Silt, fine, with occasional nodules	Brown	6	379
Sand, fine and hard	Grey	2	381
Sand, fine and medium hard	Grey	2	383
Silt, fine	Grey	21	404
Silt with abundance of nodules	Grey	4	408
Sandy silt, fine	Yellow	2	410
Clayey silt, fine	Reddish brown	20	430
Clayey silt, fine	Yellow	32	462
Sand, coarse and hard	Grey	1	463
Sand, with a little clay, rather coarse	Grey	7	470
Sand, fine and very hard	Grey	2	472
Sand, fine and medium hard	Brown	8	480
Sand, coarse and medium hard	Brown	9	489
Silt, fine	Brown	2	491
Sand, hard	Grey	2	493
Sand, with a little clay	Grey	9	502
Sand, very hard (like rock)	Grey	1	503
Sand, with occasional very hard thin layers	Grey	7	510

Record of the Lucknow Artesian Well—contd.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Sand, free and medium hard	Grey	6	516
Sand, fine and soft	Grey	3	519
Sand, medium hard, free	Grey	3	522
Sandy silt, fine	Yellow	14	536
Sand, fine and hard, with a little clay	Grey	12	548
Sand, fine and hard, free	Grey	36	584
Sand, medium hard, free	Yellow	9	593
Clayey silt, very fine	Light yellow	12	605
Sand, medium hard, free	Grey	4	609
Silt, fine and soft	Yellow	13	622
Sand, fine and hard	Brown	2	624
Sand, very hard, like rock	Brown	2	626
Sand, hard and free	Brown	14	640
Sand, medium hard, free	Brown	4	644
Sand, very hard, like rock	Brown	1	645
Sand, medium hard, free	Brown	18	663
Sand, micaceous, with kankar nodules	Yellow	8	671
Sand, fine and medium hard, free	Yellow	4	675
Sand, coarse, with hard layers	Grey	8	683
Sand, coarse and very hard, like rock	Grey	2	685
Sand, extremely hard and fine, like rock	Yellow	5	690
Sand, fine, with abundance of kankar	Brown	10	700
Sand, fine, with very many hard kankar nodules	Brown	10	710
Sand, rather coarse, medium hard, with some kankar	Brown	25	735

Record of the Lucknow Artesian Well—contd.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Sandy silt	Brown	15	750
Sand, medium hard, free *water 13 ft.*	Yellow	17	767
Kankar, hard	Bluish grey	1	768
Sand, with layers of kankar nodules	Yellow	10	778
Sandy silt, with abundance of mica	Grey	5	783
Sand, with occasional kankar nodules *water 9 ft.*	Yellow	9	792
Quicksand, with abundance of mica	Grey	6	798
Kankar, hard, with a little sand	Light grey	6	804
Sand, softish and free	Grey	2	806
Sand, with abundance of nodules	Brown	8	814
Silt, very tenaceous	Brown	8	822
Kankar, very hard	Bluish grey	1	823
Sand, softish, carrying some mica	Yellow	32	855
Clayey silt, very tenaceous	Yellow	7	862
Kankar, hard, with thin streaks of sand	Bluish grey	3	865
Sand, hard and free	Yellow	5	870
Sand, medium hard	Yellow	7	877
Kankar, hard, with a little sand	Bluish grey	3	880
Sand, medium hard, with streaks of silt	Yellow	14	894
Kankar, hard, with a little sand	Bluish grey	6	900
Sand, fine, medium hard, with a little silt and some nodules	Yellow	27	927
Kankar, solid bed, hard as rock	Bluish grey	2	929
Sandy silt, very fine	Brown	7	936
Limestone, medium hard	Grey	5	941
Sand and limestone, alternate thin layers	Grey	6	947

Record of the Lucknow Artesian Well—concld.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Sandy silt, very fine	Yellow	13	960
Sand, coarse *water 2 ft.*	Grey	15	975
Sand, coarse, abundance of kankar, some mica	Grey	15	990
Quicksand, coarse *water 5 ft.*	Grey	27	1,017
Sand, coarse, abundance of kankar nodules	Grey	23	1,040
Sand, coarse and free *water 5 ft.*	Grey	15	1,055
Kankar, solid bed, very hard	Bluish grey	2	1,057
Limestone, soft, commonly called rotten limestone	Grey	7	1,064
Rotten limestone, frequent hard streaks, some nodules	Grey	16	1,080
Limey silt, *i.e.*, limey clay with a little fine sand	Yellowish brown	27	1,107
Kankar, solid bed very hard	Bluish grey	2	1,109
Limey silt, with occasional hard nodules	Yellow	24	1,133
Limestone, medium hard	Grey	2	1,135
Limey silt, alternate hard and soft thin layers	Yellow	3	1,138
Kankar, solid bed, very hard	Bluish grey	3	1,141
Limey silt, hard and soft layers, some nodules, *water 1½ ft.*	Greyish brown	7	1,148
Limey silt with occasional hard streaks	Yellow	13	1,161
Quicksand, coarse, with abundance of mica	Yellow	5	1,168*
Sand, coarse, medium hard, with nodules	Grey	23	1,189
Quicksand, coarse, with abundance of mica—*water flowed 10 gals. per minute at surface.*	Grey	13	1,202
Sand, coarse, in hard and soft layers	Grey	19	1,221
Sand, fine, rather hard, with streaks of silt	Brown	19	1,240
Clayey silt, very fine, compact and uniform	Greyish brown	96	1,336

* *Sic.* in original.

The Agra boring.

The Agra boring performed during the years 1884 to 1886 although it failed entirely to prove the existence of any artesian supply of drinkable water, is most interesting from a geological point of view, for it is the only one amongst the borings accomplished in the Indo-Gangetic alluvium that has been carried down to the underlying rock. After traversing 513 feet of alluvial strata, the boring penetrated 132 feet further into the Vindhyan formation, making the total depth 645 feet. Before the commencement of the work Mr. Medlicott was consulted as to the chances of success. He had already advocated Lucknow as a promising locality, but with respect to Agra, he was careful to state that although the existence of artesian water was possible, yet the proximity of the southern boundary of the alluvium rendered success very doubtful: the supply of water from the southern edge cannot be great, and the possible supply from the Himaláyan border cannot very well be relied upon on account of its great distance.

Like the other borings through the Ganges alluvium, the Agra well illustrates the great thickness of that formation. The fact that the alluvial formation extends up to a depth of 513 feet so near to the southern border, shows how rapidly the floor of underlying rock must shelve beneath the accumulation of fluviatile deposits. The bottom of the alluvium at Agra is only 5 feet above sea-level.

The boring was commenced on the 5th of June 1884, and it struck the bottom of the alluvium in May 1885. There remained very little chance of finding a supply of water when once the floor of older rock had been struck, and on the 7th June 1885 the boring was discontinued, agreeably to Mr. Medlicott's recommendation. It was subsequently decided by the Municipality, with the authorization of the Collector and Commissioner, to continue the experiment, and work was resumed on the 21st August of the same year, and the boring continued through rock up to the depth of 645′ 1″ which was reached in July 1886. It was then considered useless to

continue the experiment and the work of withdrawing the pipes was commenced. Five different sizes of tubes were used as shown in the following statement :—

	Size of pipe. Inches.	Length. Feet.
1.	9	30
2.	7¾	190
3.	6¼	367
4.	5¼	470
5.	4¼	490

Unlined boring, 3″ diameter.

The upper end of the 4¼″ pipe was 30 feet below ground level. As its length was 490 feet, it was sunk to a total depth of 520 feet and was lowered 7′ 4″ in the rocky strata, leaving an unlined boring of 125 feet.

While the work of withdrawing the tubes was proceeding, it was noticed that water had risen in the artesian well up to within 36 feet of the mouth of the well, and stood some 12 feet higher than the level of the sub-soil water in the neighbouring wells. Unfortunately it was not observed at what time this rise took place, whether it was when the pipes were withdrawn to the level of some of the sandy layers in the alluvium, or whether the water had been slowly percolating from the Vindhyans. In order to find out how much water was available, the tubes were again sunk at the cost of considerable difficulty, and the bore-hole cleared out, with the object of enabling pumping experiments to be carried out. The work of lowering the tubes was commenced on the 1st of January 1887, and the bore was finally cleared out on the 16th March. Pumping was commenced on the 18th March, at which date "the water was 35 feet 10 inches below the top of the masonry steining. After four

hours' continuous pumping it was 84 feet below the top of the well, which gives a fall of 49 feet, and within an hour it rose 51 feet 6 inches, actually 2½ feet higher than it originally was when pumping was first started.....The fall after pumping after the first few days.....appears to have been much less. Pumping was discontinued on the 2nd April, and on the 6th May it was found that the water was 32 feet from the top of the steining, and 16½ feet higher than the water in the well on the opposite side of the road." (Report of the Executive Engineer, dated 18th July 1887.)

At the time of these experiments, the bottom of the 4¼" tube was inserted into the Vindhyan rock to a distance of about four feet. The circumstance of the rise of water was brought to the notice of Mr. Medlicott, who was of opinion, however, that the water did not proceed from the Vindhyans: he considered that the pipes were not water-tight, and that the water probably issued from some of the arenaceous strata in the alluvium, perhaps one of those marked 30 or 32 in the list given below. The matter was also referred, at a subsequent date, to Mr. Foote, who concurred in Mr. Medlicott's opinion. Yet, as matters then stood, it was not possible to obtain absolute certainty, which is unfortunate, because this is the only boring in India that has penetrated to any depth through the Vindhyans, and it would be very interesting to obtain some accurate information as to the water-bearing capacity of these rocks, whose stratigraphical structure is in many localities eminently suited to artesian conditions.

The water was so highly charged with salts of magnesia that it was quite unfit for drinking purposes, that in the neighbouring wells being on the contrary quite sweet. As it was found deficient both in quality and in quantity, the experiment was discontinued and the pipes were withdrawn.

The following is the list of strata passed through in the Agra boring.

Record of the Agra boring—concld.

Number of stratum.	Thickness of stratum.	Depth below ground level.	Description of strata.
	Ft. in.	Ft. in.	
44	26 9	551 9	Sandstone.
45	5 3	557 0	Sandstone, softer.
46	12 0	569 0	Red and white clay with red and white sand with thin layer of sandstone.
47	4 4	573 4	Red and white clay with little sand.
48	5 8	579 0	Sandstone.
49	4 0	583 0	Red clay and soft sandstone.
50	15 9	598 9	Sandstone.
51	2 2	600 11	Red clay and soft sandstone.
52	44 2	645 1	Sandstone with iron interspersed.

The strata numbered 42 to 52 belong to the Vindhyan series.

Another boring sunk in the Gangetic alluvium was the one undertaken in the year 1887 in that part of the delta known as the Sunderbunds. The well was sunk in the hope of getting a supply of fresh water for drinking purposes, as the water in the tidal creeks and rivers is almost all brackish. The site chosen was near the residence of the Agent of the Port Canning and Land Improvement Company, at Canning, about 200 yards from the Mutla river. The experiment is interesting as it shows the possibility of obtaining fresh water from the strata that underlie the brackish water-bearing soil at the surface: a supply of perfectly fresh water was struck at the depth of 173 feet

Boring at Canning in the Sunderbunds.

from the surface. The following list of strata is given in the "Indian Engineering" of August 13th, 1887 :—

Record of a boring at Canning in the Sunderbunds.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
1	6	6	Black earth.
2	4	10	Light grey clay.
3	14	24	Dark grey clay.
4	10	34	Light grey clay.
5	21	55	Black clay, sandy.
6	71	126	Grey sand full of salt water. (This is supposed to be the same stratum of sand found at Diamond Harbour under 28 feet when sinking a well in 1882 in connection with the proposed Docks.)
7	4	130	Dark grey clay.
8	5	135	Green clay with streaks of salt.
9	3	138	Mottled clay, yellow and blue, mixed with broken shingle.
10	2	140	Blue clay.[1]
11	5	145	Yellow clay mixed with broken shingle. This clay is not salt.
12	5	150	Yellow clay with bands of blue and ochre.
13	6	156	Light grey clay, very stiff, mottled with yellow.
14	10	166	Yellow clay, very loamy.
15	7	173	Yellow earth.
16	87	260	Yellow micaceous sand; contains perfectly fresh water which rises to within 8 feet of the surface.

[1] There is a slight discrepancy between the description given in the text of the "Indian Engineering" and the indications of a section appended to it: the strata 10 and 12 are mutually transposed in the section.

Boring at Chandernagore.

An experimental boring has also been put down at Chandernagore. The boring reached a depth of 242 feet without finding water. The results have been published by Mr. Oldham in the Records of the Geological Survey[1] and are reprinted below. On the subject of this section Mr. Oldham has written the following remarks:—

"The section requires but little comment. The bed No. 13 is evidently the equivalent of the peat bed found near Calcutta at depths of from 30 to 35 feet; No. 32 is peculiar as containing numerous sub-angular fragments of felspar which must have been derived from some exposure of gneiss or granite in the neighbourhood, which has since been covered up by alluvium owing to the subsidence which has taken place in the Gangetic delta; the specimen also contains a fragment of bone, apparently of a turtle, converted into oxide of iron."

Tableau indiquant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor.

	Thickness.	Depth.	Thickness.	Depth.
	Metres.		Feet.	
No. 1. Terre végétale . . .	0·80		2·62	
„ 2. Sable fin micacé d'un blanc sale mêlé de coquilles et de nodules calcaires	1·35	2·15	4·42	70·5
„ 3. Sable fin micacé d'un blanc jaunâtre mêlé légèrement de nodules calcaires . . .	0·45	2·60	1·47	8·52
„ 4. Sable fin micacé d'un jaune rougeâtre	0·25	2·85	·82	9·34
„ 5. Sable fin micacé d'un blanc jaunâtre	0·30	3·15	·98	10·32

[1] "On a deep Boring at Chandernagore", Rec. Geol. Surv. Ind., Vol. XXVI, pp. 100-108.

Tableau indiquant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor—contd.

	Thickness.	Depth.	Thickness.	Depth.
	Metres.		Feet.	
No. 6. Sable fin micacé d'un gris cendré	0·60	3·75	1·97	12·29
„ 7. Argile sableuse d'un gris foncé	0·35	4·10	1·15	13·44
„ 8. Argile grisâtre mêlée de débris de coquilles et de nodules calcaires	0·65	4·75	2·14	15·58
„ 9. Argile d'un noir grisâtre	2·50	7·25	8·21	23·79
„ 10. Sable fin micacé grisâtre	1·40	8·65	4·59	28·38
„ 11. Argile noire plastique mêlée légèrement de concrétions ferrugineuses	0·54	9·19	1·77	30·15
„ 12. Argile noire stratifiée mêlée légèrement de bois pourris	0·65	9·84	2·13	32·28
„ 13. Tourbe	2·36	12·20	7·75	40·03
„ 14. Argile gris-noir mêlée de toutes petites concrétions ferrugineuses	1·66	13·86	5·44	45·47
„ 15. Argile grise mêlée de petites concrétions calcaires	1·00	14·86	3·28	48·75
„ 16. Argile colorée en jaune et noir mêlée de concrétions calcaires	1·90	16·76	6·23	54·98
„ 17. Argile micacée colorée légèrement en jaune par du carbonate de fer	2·10	18·86	6·90	61·88
„ 18. Argile d'un jaune pale mêlée de nodules calcaires et souillée légèrement de carbonate de fer	2·29	21·15	7·51	69·39
„ 19. Argile bleuâtre tachée en jaune par du carbonate de fer	0·40	21·55	1·31	70·70
„ 20. Argile jaunâtre mêlée de concrétions calcaires	2·25	23·80	7·38	78·08
„ 21. Argile bleuâtre colorée en rouge et en jaune par du péroxyde de fer et de carbonate de fer	0·95	24·75	3·12	81·20

Tableau indequant le nombre et la nature des couches rencontrées pendant le forage du puits artesien de Chandernagor—concld.

	Thickness.	Depth.	Thickness.	Depth.
	Metres.		Feet.	
No. 22. Argile colorée en jaune par du carbonate de fer . . .	8·38	33·13	27·50	108·70
„ 23. Argile sableuse mêlée de graviers	0·55	33·68	1·80	110·50
„ 24. Argile d'un gris pale colorée en jaune par du carbonate de fer et mêlée de nodules ferrugineuses	4·60	38·28	15·10	125·60
„ 25. Argile d'un jaune sale micacée stratifiée colorée en jaune par du carbonate de fer . .	1·15	39·43	3·77	129·37
„ 26. Argile d'un blanc sale micacée .	1·55	40·98	5·09	134·46
„ 27. Argile sableuse micacée souillée d'oxyde de fer . . .	0·55	41·53	1·80	136·26
„ 28. Argile colorée en jaune par du carbonate de fer . . .	1·03	42·56	3·37	139·63
„ 29. Ocre jaune	3·40	45·96	11·16	150·79
„ 30. Sable argileux micacé mêlé de nodules ferrugineuses . .	0·90	46·86	2·95	153·74
„ 31. Sable argileux micacé souillé d'oxyde de fer . . .	1·35	48·21	4·44	158·18
„ 32. Sable moyen et fin micacé mêlé de pétrification cailloux anguleux nodules ferrugineuses .	24·30	72·51	79·81	237·99
„ 33. Sable fin micacé grisâtre . .	1·46	73·97	·79	242·78
„ 34. Sable moyen micacé d'un blanc grisâtre	?	...	...	...

Chances of success in the Gangetic alluvium.

Thus it appears that none of the borings in the Indo-Gangetic alluvium can be called exactly successful, but the experiments have been so few and so incomplete that it would be premature to predict that a similar fate must attend all future trials. So much can be made out, that the pros-

pects appear very poor along the southern border of the basin. Nearer to the northern border the existence of artesian conditions has been definitely proved by the Lucknow boring, but the water-bearing strata lie probably everywhere at a considerable depth, and data are wanting to form any idea as to the flow that might be expected.

(3) *Other alluvial areas.*

If, from the Indo-Gangetic alluvium, we pass to the smaller alluvial plains in other parts of India, we find that there is very little to be recorded since Mr. Medlicott's general review of the subject.

The expectations raised by the success that attended the sinking of artesian wells at Pondicherry have not been fulfilled in the experiments tried in the other alluvial plains, apparently similarly situated along the east coast of the Peninsula. At Pondicherry itself, a great many wells have been sunk in addition to the four wells described in Mr. Medlicott's Report, and some of these have been very successful, but at Cuddalore, in the southern continuation of the very same alluvial plain, the trial resulted in failure.

Boring experiments at Madras.

A number of experiments have been conducted at Madras and in the neighbourhood of that town, but without much success. At Madras itself, the borings showed that the gneiss occurs at a much smaller depth than was expected, and all hopes of finding an artesian supply had to be abandoned. Already in the year 1832, a boring sunk at the old Custom House had struck the gneiss at the depth of 55 feet.[1] As it was not certain whether this might not have been only a stray boulder, another boring was undertaken in 1885 in the People's Park, but it struck the gneiss at almost exactly the same depth.[2]

[1] Journ. Royal Asiatic Society, Vol. VIII, p. 248.

[2] A complete collection has not been made of the boring records in the Madras Presidency so as not to defer the publication of the present report, but a number of the more important experiments have been described from information available in the Geological Survey Office.

The following extracts are from a report of the Public Works Department, dated 28th July 1885: "..... Government accepted an offer from M. Cornet, a French Engineer, to make the experiment of sinking an artesian well at Madras. The maximum depth named for the experiment was 120 metres, or 393 feet; and it was expected that, if the result proved favourable, three months would suffice to complete the work. The approximate estimate of the cost of the well was put down at R15,475.

"The People's Park having been suggested by Dr. King, of the Geological Survey of India, as a locality likely to prove favourable for such an experiment, a site was selected therein, and work was commenced on the 24th March 1885. For a depth of 58 feet the boring was through soil consisting of clay, marl, sand, etc., below which a granitic formation was met with, into which the boring proceeded slowly, the rock being of excessive hardness.

"In order to ascertain whether the rock which had been encountered was a detached boulder, or an extensive underlying bed, a trial boring of small diameter was made at a distance of some 50 yards south of the first site. In this second boring, granite of precisely similar character was reached at the same depth, a result which went to show that the bed was continuous. M. Cornet then proceeded to examine three artesian borings which had been attempted in the vicinity of Madras by private enterprise. From samples of the strata through which these borings had passed, M. Cornet arrived at the conclusion that, from Fort St. George to a distance of six or seven miles north, and a mile or two inland, the underlying strata are everywhere identical and consequently unlikely to yield an artesian supply of water."

Borings in the Kortalayar Plain.

The chances appear to be more promising in the alluvial plain of the Kortalayar river, situated further north. The alluvium occupying this plain has been deposited partly by the Kortalayar; but formerly a larger river also contributed to its formation, the Pálár, which now flows in a different

direction. A boring was put down by private enterprise through these strata in the year 1883, near Ennur. A water-bearing stratum was struck at a depth of 65 metres (213 feet). There does not appear to exist any detailed record of the boring: it reached a depth of 214 feet in September 1884, but by that time it had proceeded beyond the alluvium and had penetrated the underlying tertiary and jurassic beds.

The Karani boring.

In June 1886, a boring was commenced at Government expense at Karani in the Kortalayar valley. The result was disappointing as only two sheets of water were met with at depths of ten and forty feet, neither of which were very abundant. The boring was continued to a depth of 442 feet without striking any other supply. The list of strata encountered is given below. According to Mr. Foote it is doubtful whether all these strata belong to the recent alluvial deposits of the Kortalayar and Pálár. Just as in the experiment at Ennur, it is possible that the lower part of the boring has been sunk through rocks older than the alluvial, in the present case the "Cuddalore sandstone" of tertiary (or pleistocene) age.

Section of the Karani boring.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
1	4·50	4·50	Sandy vegetable mould, yellowish, then black clay with a small portion of sand.
2	2·50	7·00	Fine yellowish sand with a few pieces of kankar.
3	4·00	11·00	Greyish sand with a little clay and pieces of kankar. Water sheet at 10 feet.
4	2·00	13·00	Fine yellowish sand with some kankar.

Section of the Karani boring—contd.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
5	12·00	25·00	Sandy clay yellowish brown mixed with some blue clay nodules and pieces of kankar; clay passing to whitish yellow mixed with sand.
6	6·00	31·00	Yellow and white clay with kankar in small quantity.
7	6·00	37·00	Yellow-brown clay with more kankar, passing to conglomerate with patches of green and white clay, and fragments of laterite transported by water.
8	4·00	41·00	Very hard yellow clay, whitish when dry; at 38 feet, pieces of white coral passing to reddish-brown.
9	2·50	43·50	Yellowish coarse sand mixed with clay.
10	6·12	49·62	Coarse river sand mixed with clay. The strata 9 and 10 contain water under pressure which rose to within 3′ 3″ of the ground-level in November 1886. In March 1887, the surface of the water was 6′ 9″ below ground-level.
11	2·03	51·65	Fine sand mixed with yellow clay.
12	1·75	53·40	White clay with portions of yellow clay like laterite.
13	5·25	58·65	Very hard sandy yellow clay with water-worn fragments of gneiss.
14	12·00	70·65	Similar stratum containing fine sand mixed with clay, coarse river sand, and a few pebbles.
15	12·00	82·65	Very stiff yellow clay mixed with red and grey clay in patches and layers, containing water-worn fragments of laterite. Becomes arenaceous at 80 ft.
16	0·75	83·40	Bed of limestone.
17	3·00	86·40	Yellow clay mixed with some white clay and layers of grit.

Section of the Karani boring—contd.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
18	1·75	88·15	Some yellow clay, mixed with red clay.
19	5·50	93·65	Clay resembling laterite, containing pebbles and sand derived from the primary rocks.
20	7·00	100·65	Hard yellow clay mixed with sand and fragments of gneiss; then hard greyish clay mixed with yellowish clay. At 99 feet, more grey clay passing to blue clay.
21	3·00	103·65	Grey clay traversed by blue clay.
22	3·00	106·65	Blue clay mixed with some yellow clay.
23	5·18	111·83	Stiff yellow clay.
24	1·28	113·11	Stiff yellow clay traversed by blue clay.
25	45·77	158·88	Very hard indurated blue clay with a few layers of grit.
26	2·30	161·18	Greyish limestone, the lower part of which is very hard.
27	18·92	180·10	Blue clay and layers of grit. The lower part of the stratum contains iron-pyrites.
28	10·86	190·96	Fine blackish grey sand with iron pyrites, mixed with very hard indurated blue clay, containing sometimes layers of grit and limestone.
29	1·00	191·96	Very hard greyish limestone.
30	9·04	201·00	Fine blackish grey sand with iron pyrites, mixed with very hard indurated blue clay, containing sometimes layers of grit and limestone.
31	6·00	207·00	Fine blackish blue stiff clay; lower part greyish.
32	1·00	208·00	Very hard grey limestone.
33	2·50	210·50	Fine indurated greyish clay, with a little sand.

Section of the Karani boring—contd.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
34	6·00	216·50	Very hard black clay; lower part containing layers of grit.
35	6·25	222·75	Very hard grey limestone.
36	7·00	229·75	Grey sand with indurated clay.
37	13·00	242·75	Indurated grey sand mixed with clay, pieces of shell and decayed leaves, and nodules of carbonate of lime.
38	7·00	249·75	Indurated grey sand containing clay and fragments of shells.
39	4·00	253·75	Indurated grey sand mixed with clay.
40	4·00	257·75	Indurated grey sandy clay passing into conglomerate containing fragments of kankar.
41	54·25	312·00	Coarse sand with greyish clay.
42	5·00	317·00	Black clay.
43	0·75	317·75	Grey limestone.
44	2·25	320·00	Black clay.
45	1·00	321·00	Grey limestone.
46	27·00	348·00	Black clay.
47	1·00	349·00	Grey limestone.
48	2·00	351 00	Grey sand mixed with clay.
49	4·00	355·00	Black clay.
50	12·00	367·00	Hard grey clay.
51	2·00	369·00	Grey limestone.
52	0·50	369·50	Layers of grit.
53	0·75	370·25	Grey sandy clay.

Section of the Karani boring—concld.

Number of stratum.	Thickness of stratum.	Depth below ground-level.	Description of strata.
	Feet.	Feet.	
54	37·75	408·00	Black clay; upper part contains fragments of decayed wood and broken shells.
55	4·00	412·00	Grey sand mixed with clay.
56	4·00	416·00	Indurated black clay.
57	2·00	418·00	Grey sand mixed with a little clay.
58	1·00	419·00	Indurated black clay.
59	1·00	420·00	Grey sand with clay.
60	21·00	441·00	Grey clay with sand.
61	1·00	442·00	Limestone.

The altitude of the ground at the mouth of the well is 71 feet above sea-level.

Coconada boring.

A successful experiment has been made lately at Coconada, on the sea-coast in the northern part of the delta of the Godavári.

But here, in all probability, the greatest part of the boring is not through alluvium, but through the "Rajahmundry beds," a local facies of the Cuddalore sandstones. An abundant supply of water was struck at a depth of 295 feet, the water overflowing at a height of about one foot and a half above the surface of the ground. The "Rajahmundry beds" consist of alternating layers of sandstone and clay. They outcrop over a considerable area to the north-west of Coconada, and as they dip under the alluvium at a low angle in a south-south-east direction towards the sea-coast, they ought to be very favourably situated with respect to artesian conditions.

The following list of the strata met with has been kindly communicated by the Engineer-in-Chief of the East Coast Railway:—

Section of Artesian Well boring at Coconada Town.

Number of stratum.	Thickness of stratum.	Total depth from top of spoil bank.	Description of strata.
	Feet. In.	Feet. In.	
1	10 0	10 0	Sand.
2	20 0	30 0	Clay.
3	80 0	110 0	Clay and a few pebbles, then clay and sand.
4	30 0	140 0	Clay.
5	10 0	150 0	Sand.
6	70 0	220 0	Clay, then decomposed rock.
7	10 0	230 0	Sand and soft sandstone.
8	48 0	278 0	Clay.
9	1 0	279 0	Decomposed rock and coarse sand.
10	1 0	280 0	Disintegrated rock.
11	9 0	289 0	Coarse sand.
12	1 0	290 0	Sand conglomerate.
13	1 9	291 9	Sand.
14	0 3	292 0	Soft sandstone.
15	3 0	295 0	Sand.

Tank spoil bank level about 3 feet above ground-level. Water level in pipe at a depth of 1′ 6″. Diameter of bore-hole, 8½ in. Total depth of lining 290 feet.

An experimental boring is being conducted at present in another part of the alluvial deposits of the Godávari at Ellore. But as it seems certain that it is at present in Gondwana rocks, it will be

mentioned again in connection with other experiments carried out in rocks of that class.

Karikal boring.

A trial was also made in 1881-82 at Karikal, a town whose geographical and geological situation resembles that of Pondicherry. The undertaking did not meet with the same success as at Pondicherry although two artesian sheets were struck, the first one at a depth of 346 feet, which rose to within 4 inches of the surface, and a second one at a depth of 347 feet, which overflowed. The hydrostatic head of the latter was 6½ feet above the level of the ground, but its delivery was only 22 gallons a minute. A copy of the boring record communicated by the French Government Engineer is herewith appended. Like the Chandernagore boring record, it is printed in the original language with only the addition of the measurements in feet:—

Coupe géologique du Puits Artésien de Karikel.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	Description of strata.
1	2·00	2·00	6·56	6·5	Terrain naturel. Sable gris-noir terreux.
2	0·45	2·45	1·47	8·0	Sable gris-noir terreux avec mélange de sable jaune-brun fin.
3	0·79	3·24	2·59	10·6	Sable gris-noir argileux.
4	1·04	4·28	3·41	14·0	Argile noire plastique avec oxyde de fer et mêlée de sable blanc, gris et jaune-brun.
5	1·02	5·30	3·34	17·3	Argine jaune-brun mêlée de sable.
6	1·40	6·70	4·59	21·9	Sable fin jaune-brun avec petits graviers.
7	0·75	7·45	2·46	24·4	Sable moyen jaunâtre avec graviers et grès ferrugineux.

Coupe géologique du Puits Artésien de Karikel—contd.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground level in feet.	Description of strata.
8	1·05	8·50	3·44	27·8	Sable fin micacé jaune pâle.
9	1·10	9·60	3·60	31·4	Argile grise avec mélange de terre de soude.
10	3·15	12·75	10·33	41·8	Argile brune mêlée de sable.
11	1·10	13·85	3·60	45·4	Argile sableuse rougeâtre.
12	1·45	15·30	4·75	50·1	Sable argileux jaunâtre avec grès ferrugineux.
13	0·36	15·66	1·18	51·3	Sable gros argileux jaune-pâle avec petits graviers.
14	0·30	15·96	0·98	52·3	Sable fin micacé fluide.
15	1·74	17·70	5·70	58·0	Argile brune sableuse.
16	3·15	20·85	10·33	68·4	Sable jaune clair fin.
17	0·57	21·42	1·87	70·2	Sable gros argileux gris-clair avec graviers et choukan.
18	0·53	21·95	1·73	72·0	Terre de sonde fluide.
19	0·85	22·80	2·78	74·7	Sable moyen gris avec terre de soude, mottes d'argile irisée et choukan.
20	2·70	25·50	8·85	83·6	Argile brune sableuse irisée avec choukan.
21	4·45	29·95	14·60	98·2	Argile irisée mêlée de terre de soude.
22	0·80	30·75	2·62	100·8	Argile irisée mêlée de sable fin micacé.
23	0·65	31·40	2·13	103·0	Argile gris-noire avec agglomérats.
24	0·45	31·85	1·47	104·4	Argile brune sableuse avec agglomérats.
25	0·30	32·15	0·98	105·4	Argile schisteuse irisée.

Coupe géologique du Puits Artésien de Karikel—contd.

Number of stratum.	Thickness of stratum in feet.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	Description of strata.
26	2·25	34·40	7·38	112·8	Sable fin micacé jaune pâle avec agglomérats.
27	13·00	47·40	42·65	155·5	Sable fin jaune-brune avec grès ferrugineux, cailloux et graviers.
28	2·20	49·60	7·21	162·7	Argile brune mêlée de sable fin micacé.
29	0·80	50·40	2·62	165·3	Sable moyen jaune pâle avec petit graviers.
30	2·10	52·50	6·88	172·2	Argile brune sableuse.
31	0·80	53·30	2·62	174·8	Argile gris-noire marbrée avec agglomérats.
32	3·15	56·45	10·33	185·1	Argile sableuse irisée avec agglomérats.
33	0·23	56·68	0·75	185·9	Sable rougeâtre argileux, avec cailloux, graviers, gres ferrugineux et débris de coquilles.
34	0·55	57·23	1·80	187·7	Agglomération.
35	0·35	57·58	1·14	188·8	Sable argileux jaune rougeâtre avec petits graviers et cailloux.
36	1·67	59·25	5·47	194·3	Sable moyen sali d'argile jaunâtre et mêlé de petits graviers.
37	3·00	62·25	9·84	204·1	Argile irisée compacte avec rognons d'agglomération.
38	1·25	63·50	4·10	208·3	Argile irisée mêlée de sable fin et avec agglomération.
39	0·65	64·15	2·13	210·4	Argile compacte irisée avec rognons d'agglomérats.

Coupe géologique du Puits Artésien de Karikel—contd.

Number of stratum.	Thickness of stratum in metres.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	Description of strata.
40	0·75	64·90	2·46	212·9	Argile gris-cendrée irisée avec rognons d'agglomérats.
41	1·05	65·95	3·44	216·3	Argile jaune-rougeâtre irisée mêlée de sable et de graviers et souillée d'oxyde de fer.
42	0·10	66·05	0·32	216·6	Agglomération.
43	0·40	66·45	1·31	217·9	Sable fin jaune pâle avec graviers et débris de coquilles.
44	0·25	66·70	8·82	218·8	Agglomération.
45	0·50	67·20	1·64	220·4	Sable moyen rousseâtre sali d'argile.
46	0·55	67·75	1·80	222·2	Argile sableuse irisée avec graviers et agglomérats.
47	0·40	68·15	1·31	223·5	Argile sablonneuse irisée.
48	1·05	69·20	3·44	227·0	Sable fin souillé d'ocre-jaune et mêlé de débris de coquilles.
49	0·10	69·30	0·32	227·3	Agglomération.
50	0·70	70·00	2·29	229·6	Sable moyen jaunâtre sali d'argile et mêlé de graviers.
51	0·40	70·40	1·31	230·9	Agglomération.
52	4·18	74·58	13·71	244·6	Sable moyen jaunâtre souillé d'argile et mêlé de petits graviers, de débris de coquilles et de rognons d'agglomérats.
53	0·62	75·20	2·03	276·7	Agglomération.
54	1·35	76·55	4·42	251·1	Sable fin jaunâtre souillé d'argile.

Coupe géologique du Puits Artésien de Karikel—concld.

Number of stratum.	Thickness of stratum in feet.	Depth from ground-level in metres.	Thickness of stratum in feet.	Depth from ground-level in feet.	Description of strata.
55	1·15	77·70	3·77	254·9	Sable moyen jaunâtre argileux avec débris de coquilles et rognons d'agglomération.
56	6·75	84·45	22·14	277·0	Argile noire plastique mêlée de coquilles et d'argile blanche.
57	0·80	85·25	2·62	279·6	Sable argileux noirâtre avec petits graviers et cailloux et traces de coquilles.
58	0·45	85·70	1·47	281·1	Agglomération pierreuse de couleur gris-âtre.
59	3·67	89·37	12·04	293·1	Sable argileux moyen, de couleur gris-âtre avec mélange de cailloux, de graviers et de coquilles.
60	0·20	89·57	0·65	293·8	Agglomération.
61	0·63	90·20	2·06	295·9	Argile gris-noire claire mêlée de graviers, cailloux et débris de coquilles.
62	1·50	91·70	4·92	300·8	Argile gris-noire mêlée de sable fin.
63	9·86	101·56	32·34	333·1	Argile grise mêlée de sable de graviers, cailloux, boispourris, et rognons d'agglomération.
64	0·30	101·86	0·98	334·1	Agglomération.
65	3·35	105·21	11·09	345·2	Sable gris-noir argileux avec cailloux, graviers et débris de coquilles.
66	0·30	105·51	0·98	346·1	Agglomération.
67	0·20	105·71	0·65	346·8	Sable gris fin pur.
68	0·10	105·81	0·32	347·1	Agglomération.
69	1·59	107·40	5·21	352·3	Sable gros gris pur avec graviers cailloux.

Wells at Rangoon.

A considerable portion of Burmah is occupied by alluvium, and it is probable that there are places where the conditions are favourable to artesian action. The "tube-wells" sunk in the alluvium of Rangoon appear to be partly artesian in their characters, although in none of them does the water overflow. They are situated close to the banks of the Rangoon river and the Poozoondoung creek, and as the water in the deep-seated water-bearing sands appears to flow very freely from the direction of the higher ground round the Shway Dagon pagoda hill towards the river banks, the pressure is not sufficient to cause any overflow in such a situation: the water does not rise to within less than 5 to 11 feet from the surface. Mr. Oldham, who has written an account[1] on the subject of these wells from which the present information is gathered, was of opinion that flowing wells might be obtained further inland, though the rise of the ground is so slight that no great increase of the pressure can be expected. As to any scheme of supplying the town with water from this source, Mr. Oldham pointed out that the yield of the wells is not very large (the wells then in existence gave amounts varying from 2,500 to 70,000 gallons a day), and that, owing to irregularities common in all alluvial formations, a certain number of the proposed wells are sure to be failures: hence "a large number of wells will therefore have to be sunk if the requisite supply of water is to be obtained, and it seems probable that, when the estimates are made out, it will be found that the cost will be nearly if not quite as great as for the construction of a storage reservoir, while the cost of maintenance and uncertainty of success will be much greater."

Some of the wells go down to depths of as much as 320 feet. The strata encountered belonging to the "newer alluvium" above, and the "older alluvium" below, as defined by Mr. Theobald in his survey of the geology of the district. The fact that below a

[1] Note on the alluvial deposits and subterranean water-supply of Rangoon. Rec. Geol. Surv. Ind., Vol. XXVI, pp. 64-70.

certain point on the banks of both the Rangoon river and the Poozoondoung creek, all the wells contain more or less brackish water shows that there is very free underground communication, and that "there is a continuous outflow from the outcrop of the gravels to the sea," the permeable sands not being perfectly enclosed by watertight strata.

Mr. Oldham gives the following description of the method by which the wells were sunk :—" they are cased with iron piping of from $2\frac{1}{2}$" to 4" internal diameter, which was sunk by the simple process of forcing a stream of water down a smaller tube of from 1" to 2" bore, inserted in the centre of the outer casing. The stream of water ascending the annular space between the two tubes carried with it the material washed from the bottom of the bore, and so enabled the two tubes to be sunk simultaneously ; when the well was completed, the inner tube was withdrawn and a pump attached to the outer one. This process appears to be simple, inexpensive, expeditious, and effectual, though of course only applicable in soft and not too coarse grained deposits, but it has an effect on the stuff washed out that must be allowed for. The stream of water which is sufficient to wash away fine clays or sands, would be insufficient to bring up coarse grit and small pebbles to the surface. Consequently if pebbles are mixed with fine sand or clayey matter, the stream, which has sufficient power to bring the pebbles to the surface, will wash away all the finer matter, and so what would seem to be a clean gravel, to judge from the washed material brought up, might really be a mixture of pebbles and clayey sand, of very little value as a source of water. "

With respect to the boring records appended below, Mr. Oldham makes the following remarks :—

" Most of these sections have been preserved in glass fronted boxes, in which the different layers are arranged one above the other. In some cases this has been done to scale, and there was no difficulty in determining the depths and thicknesses, in others no fixed scale was followed, and the depths are indicated by

paper slips affixed to the glass, a much inferior plan, for when, as has sometimes happened, any of these labels have peeled off, it is impossible to determine the true thickness of some of the layers. Where I have not seen the specimens, or none have been preserved, the section is given by repute. The term grit is used to indicate a texture intermediate between that of sand and of gravel, the limits of size of the individual grains may be taken as $\frac{1}{32}$ and $\frac{1}{8}$ inch. The horizontal line indicates the base of the newer alluvium."

Detailed sections of borings.

No. 1. Mohr Brothers.

There are two wells, the section of the deepest is—

0—109 ft. fine grey clayey silt.
109—136 „ fine grey sand.
136—180 „ grey clayey silt.
180—190 „ yellowish sand (silt of the newer alluvium mixed with sand grains of the older).

190—210 ft. sand.
210—220 „ fine gravel ranging to $\frac{1}{4}$" diameter.
220—270 „ coarser gravel, some pebbles as much as an inch in diameter.
below 270 feet, yellow sand again.

No. 2. Bulloch Brothers & Co.

One well, section said to be—

0— 90 ft. clay.
90— 96 „ sand.
96—220 „ clay.
220—240 „ yellow sand and gravel.

No. 3. Diekmann Barckhausen & Co.

One well, 242 feet deep. No record.

No. 4. Steel Brothers & Co. Upper mill.

Two wells, 50 feet apart. There is a distinct difference in the water of the two. One contains a small proportion of oily matter, probably petroleum, which floats on the surface of the water. Section—

0— 30 ft. fine brown silt.
30— 40 „ dirty yellowish sand.

40— 60 ft. grey sandy silt.
60— 70 „ fine sand.
70— 80 „ yellowish sand.

80— 85 ft. fine grey sand.
85—100 „ brown earth.
100— „ yellow sand.
—175 „ coarse grit and sand.
175—190 „ coarse grit.
190—210 „ fine gravel.
210—238 „ gravel ranging to ½ inch in diameter.

No. 5. Steel Brothers & Co. Middle mill. Section—

0— 85 ft. grey clayey silt.
85— 99 „ fine sand.
99—100 „ grey sandy silt.
100—118 „ fine grey sand.
118—122 „ grey sand with yellowish grains.
122—130 „ fine grey silt.

130—145 ft. clean sand.
145—150 „ coarse grit with some fragments ranging to ½ inch in diameter.
150—155 „ grey silt.
155—160 „ coarse sand mixed with small ferruginous concretions
160—176 „ fine clean sand.
176—180 „ fine reddish sand.
180—190 „ coarse sand.
190—195 „ medium grained yellow sand.
195—198 „ grit.
198—203 „ coarse grit with some larger fragments.
203—229 „ gravel ranging to ½ inch.

No. 6. Kruger & Co.

Section lost. At about 250 feet a large number of shells in a very good state of preservation and in some cases quite fresh looking were brought up. The forms are all marine littoral, comprising the genera *Cardium*, *Arca*, *Venus*, *Solen*, besides fragments of polyzoa. The species appear to be living ones.

No. 9. Zaretskey Book & Co. Section—

0— 30	ft. grey silt.
30— 42	„ fine brownish sand.
42— 55	„ small ferruginous concretions.
55—125	„ grey clayey silt.
123—217	„ grey sand.
217—220	ft. sub-angular gravel.
220—249	„ fine pale buff sand.
249—254	„ pale yellow sand.
254—257	„ coarse grit and sand.
257—289	„ pale yellow sand.
289—	„ coarse grit and sand.

"Through the courtesy of the proprietors this well was pumped for me with an open mouth. It was found that the well gave 1,200 gallons an hour with a lowering of the surface level to 8 feet."

No. 7. Steel Brothers & Co. Lower mill.

No record except that the water was brackish.

No. 8. Rowett & Co.

Two wells were sunk, both were failures. No further record.

No. 10. Bulloch Brothers & Co. Section—

0— 25	ft. fine clayey silt.
25— 52	„ fine sandy silt.
52— 70	„ fine grey sand.
70—108	„ silt.
108—118	„ fine grey sand.
118—170	„ alterations of more or less sandy and clayey silt.
170—256	„ grey sand of various shades.
256—265	„ grey sand with some yellow grains.
265—275	ft. yellow sand.
275—282	„ grit.
282—302	„ sharp yellow sand.
302—320	„ gravel ranging to ¼ inch.

No. 11. Arracan Co.

Two wells sunk to 240 and 245 feet; water bad. No further record.

No. 12. Arracan Co.

One well of 140 feet. Water not good. No further record.

No. 13. Victoria Oil works. Section—

0— 20 ft. grey clayey silt.
20— 80 „ fine grey sand.

80—100 ft. yellowish sand.
100—120 „ fine sub-angular gravel.
120—134 „ pepper and salt grey sand.
134—155 „ sand with small pebbles.
155—190 „ sand.
190—215 „ small sub-angular gravel.
215—218 „ sand.
218—230 „ gravel mostly small, imperfectly rounded, with some fragments of ½ inch across.
230—236 „ fine sand.
236—240 „ gravel as before.
240—250 „ fine grey sandy silt.
250—257 „ coarse grit.
257—265 „ fine white sand.
265—273 „ sand and grit.
273—276 „ white sand.
276—279 „ white grit.
279— „ gravel, ¼ to ½ inch.

No. 14. Irrawady Flotilla Co.

One well of 170 feet, water brackish. No further records.

No. 15. McGregor Brothers & Co. Section said to be—

0— 50 ft. blue clay.
50— 62 „ red clay.
62— 96 „ sand.
96—224 „ gravel, then sand and thin beds of white clay
224—228 „ gravel.

No. 16. Foucar Brothers & Co.

No record.

No. 17. Bulloch Brothers & Co. Section—

0— 30 ft. brownish silt.
30— 43 „ grey silt.

43— 62 ft. brick red clayey matter (soft laterite?).
62— 68 „ fine buff sand.
68— 75 „ fine pale greyish sand.
75—110 „ yellow sand.
110—130 „ clean sharp sand.
130—148 „ grit.
148—161 „ yellowish sharp sand.
161—165 „ fine brown sand.
165—171 „ coarse sand.
171—180 „ coarse sub-angular grit.
180—185 „ gravel up to an inch in diameter.

No. 18. Heatherington Gray & Co.
One well of 250 ft. Water bad; no record.

No. 19. Mohr Brothers & Co. Section—

0— ft. fine grey silt.
—196 „ grey silt mixed with grains of reddish sand.

196— ft. grey sand with some small pebbles.
—210 „ clean yellow sand.
210—215 „ coarse sand.
215— „ small gravel.
—224 „ coarse grit.
224—230 „ fine grit and coarse sand.
230—242 „ sub-angular gravel ranging to ¼ inch.

Boring at Akyab.

An experimental well was sunk at Akyab in 1889-1890. But it is difficult to make out how far the work proceeded through alluvium, or whether it entered the underlying tertiary rocks. The locality was visited in 1897 by the late Mr. Grimes, who wrote the following particulars on this subject: "In the years 1889-90, at the Arracan Company's Upper Mill, on the north side of the town of Akyab, a well was bored to a depth of 421 feet, for the purpose of obtaining water, but without

any success. The only record of this boring which I could obtain was in a letter from the Arracan Company to the Akyab Municipal Commissioners, in which they write that at 421 feet they reached a stiff clay and could make no further progress, and that long before they reached the clay they went through several layers of sand and gravel, but there was no sign of water anywhere. This is very indefinite as it does not show how much of this depth was bored in the alluvial beds or whether it was even entirely in the alluvium. Wells sunk close to the ridge of rocks get down through the alluvium to the underlying rock at a very moderate depth, but there is evidence to show that the thickness of the recent deposits increases as one gets away from this ridge, and the increase is possibly very rapid."

(4) *Gujárát.*

A large portion of Gujárát is covered with alluvium, but not to any depth comparable with that of the Indo-Gangetic plain. The subject of artesian wells has received a certain amount of attention in that province because irrigation is needed to supplement occasional deficiency of rainfall, and also on account of the fact that in many places the water of the wells is hard and brackish. Although the depth of the alluvium is inconsiderable, very little is known concerning the older rocks underlying it. So far as can be made out, the Gulf of Cambay seems to occupy a shallow basin of disturbance; the various strata, both to the east and west, dipping at low angles under the alluvium. The structure therefore is favourable to the formation of an artesian reservoir, provided that some of the strata have a capacity for transmitting water. In all probability the rocks underlying the alluvium are basaltic strata of the "Deccan trap" overlaid by tertiary strata If, as is not improbable, the lowest strata of the tertiaries are coarse gravel beds resting upon the surface of the volcanic layers, thi circumstance combined with the

Structure in the neighbourhood of the Gulf of Cambay.

abundance of overlying impermeable clays that form such a large proportion of the tertiaries, would give rise to conditions eminently suited to artesian action. So far, however, no borings have penetrated to such a depth. The boring sunk at Gogah by Lieutenant Fulljames in 1836-1839, to a depth of 354 feet 9 inches, mention of which is made in Mr. Medlicott's Report, still remains the most important attempt, and it never reached the base of the tertiaries.

Salt-bearing strata.

Some of the tertiary strata contain strings and crystals of rock-salt within their layers, and it seems to be owing to this circumstance that the wells in some parts of Gujárát contain brackish water. The behaviour of the wells varies according to the depth at which these salt-bearing strata lie below the surface. It may happen that the well, when first sunk, contains fresh water from surface layers unaffected by the brackish water lower down; but if the demand upon the water-supply in the well increases beyond a certain extent, the brackish water may percolate from below. This is particularly liable to occur in seasons of exceptional dryness when the general level of sub-soil water has been lowered, and the communication thus established with the deeper layers of contaminated water may cause the wells to become permanently deteriorated.

Fresh water-supply tapped by borings of moderate depth.

In places thus situated, a supply of perfectly fresh water has sometimes been tapped by sinking a pipe from the bottom of the well, until it penetrated through some layer of impermeable clay. Separated by this impermeable bed from the upper layer of saline water, the supply thus obtained is artesian in the strict sense of the term, although the water may not rise higher than the level of ordinary ground-water.

Experiments at Naosari.

Some very successful attempts of this class have been made by Mr. G. W. Tata at Naosari, an abundant supply of fresh water being obtained at a depth of about 150 feet.

Report by Mr. Griesbach.

The country was visited by the Director of the Geological Survey, Mr. Griesbach, at the commencement of the year, and the following remarks are extracted from his notes.

Notes on the chances of finding Artesian water in Gujárát.

"(1) Gujárát with the adjoining districts, Cutch, Kathiawar, Mahi Kantha and the Panch Mahals may, for the purposes of the water inquiry, be roughly divided into three well-defined areas, which differ stucturally from one another. There are (*a*) the hilly tracts which include the Mahi Kantha and Panch Mahals; (*b*) the Cutch and Kathiawar States, which fringe Gujárát along the south-west; and (*c*) the flat country between the hill tracts which is formed by the drainage running into the Gulfs of Cutch and of Cambay.

(2) The hilly tracts of the Mahi Kantha and Panch Mahals consist chiefly of older rocks, both schistose and crystalline, both much disturbed. Several of the valleys within this area are filled with recent deposits, but there is no evidence to show that a search for artesian water will meet with any success within these deposits.

(3) The areas of Cutch and Kathiawar which form the south-western fringe of Gujárát are chiefly built up of younger sedimentary strata (both cretaceous and tertiary beds) which are associated with the so-called Deccan trap, and I think it is extremely unlikely that within this area artesian conditions will be met with, although even so much cannot be absolutely insisted upon, but the general geological structure is certainly not promising, and I would not advocate the outlay of money on a systematic search for such a water-supply, especially as water may in most instances be found within reasonable depths by digging ordinary wells.

(4) It appears to me that the only part of the northern division of the Bombay Presidency, within which a search for artesian water

might be successful, is Gujárát proper, that is the flat country inclosed by the Mahi Kantha on one side and Kathiawar on the other. It appears to be entirely covered by widespread alluvial deposits, and very little is known of the underground geological conditions, but a few exposures in quarries and wells afford some information, which is sufficient to permit forming a favourable opinion on the chances of meeting with deep-seated supplies of water if borings were undertaken.

The few exposures of underground structure which I have seen seem to indicate that the alluvial deposits cover up a series of beds of upper jurassic or cretaceous age, consisting chiefly of sandstones and shales, and overlaid by tertiary clays, shales and limestones, the whole of which sequence of beds rests upon the old palæozoic rocks of the so-called 'Aravalli type.'

(5) The evidence in support of this supposition is somewhat meagre; besides the geological surveys of Kathiawar and Baroda, we possess surveys of the alluvium of parts of the Ahmedabad district, whilst important evidence is afforded by quarries and newly-constructed wells near Wadhwan.

(6) I have satisfied myself that we have at least two distinct water-levels within this area. The lower one is found wherever the cretaceous marls and impure limestones, which may be seen along the boundary of Gujárát and Kathiawar, are pierced down to the underlying coarse brown sandstone of cretaceous or upper jurassic age. This may be clearly observed in all the quarries near Wadhwan itself.

The upper water-level is found in the tertiary (probable upper eocene) concretionary limestone which seems to overlie the cretaceous deposits of Wadhwan unconformably (much of the so-called kankar beds appear to be the same concretionary limestone of the upper eocene which may easily be mistaken for the genuine kankar deposits of the alluvium).

If a bore-hole were sunk 7 or 8 miles north-east of Wadhwan, for instance, it would probably encounter the following series of beds in succeeding order :—

1. Alluvium, probably 10 to 20 feet.
2. Tertiary limestones and marls,—some 40 to 60 feet.

⋮

Upper Water-level.

⋮

3. Unknown strata, probably of tertiary age and of unknown thickness.

⋮

4. Upper cretaceous limestones and marls.
5. Brown sandstone, cretaceous or jurassic.

Lower Water-level.

⋮

6. Unknown strata below.

It will be seen therefore that water would certainly be obtained by boring, and it may be that by driving the boring down to the lower water-level indicated above, artesian conditions will be encountered. The proposition appears to me hopeful, and I would suggest that such a bore-hole be constructed of at least 1,000 ft. depth in the neighbourhood, say, 7 miles north-east of Wadhwan.

(8) Experiments made in former years, and the experience gained in well sinking, have proved that water may be obtained almost everywhere in Gujárát,—although in varying depths. It appears also, that much of the water-supply from wells is more or less brackish and becomes often unfit for either drinking or irrigation

purposes during abnormally dry seasons. I venture to suggest that this difficulty will only be met with in comparatively shallow wells, which are constructed in the tertiary (eocene) beds and which, as we know, contain a great deal of salt in the form of strings and pockets and even in well-defined layers. I believe that borings sunk to below the cretaceous marls will meet with sweet water in sufficient abundance to neutralize the presence of the more brackish springs near the surface. None of the older bore-holes have gone to any great depths, and I believe that the deepest bore-hole (near Broach) made by Lieut. Fulljames in 1836 to 1839 did not reach 400 ft., so that it would be premature to pronounce against the possibility of obtaining an artesian supply of sweet water within Gujárát proper."

Flowing pipe in the bed of the Mahi River.

A very interesting occurrence is recorded in a report by Mr. F. D. Campbell, Executive Engineer on Special Duty, dated 9th February 1885. It is described as "that of the pipe now discharging in the bed of the Mahi river which was lately sunk at the time when some work connected with the foundation of the railway bridge piers was in progress. The end of that pipe entered at some depth a highly porous stratum, and the supply of water in it is so constant, that a jet or fountain, 6 feet high above the low water-level, is obtained, and, according to Mr. Crosthwaite's report, this water will rise in a pipe to 15 feet above that level; but this would still be 90 feet below that of the surface of the country, and would probably correspond with that in the wells not far from the river banks." The action in this case is properly speaking artesian, although not regarded as such by Mr. Campbell. Whenever the surface of the land is deeply cut into by the channel of a river, the level of saturation of the ground sinks rapidly in the neighbourhood of the river banks on account of the flow of undergound water towards the channel. Owing to the irregular disposition of permeable and impermeable layers common to all alluvial formations, one of the water-bearing strata underneath

the river-bed might be enclosed by impervious strata in such a manner as to derive its supply from an area situated at no great distance from the river, but where the surface of the ground-water stands at a somewhat greater altitude than in the immediate neighbourhood of the river. It is probable that a similar phenomenon might take place in many river-beds; but in such a position the supply is usually not of much use. Of a similar nature is the occurrence mentioned by Mr. Medlicott as having taken place in the year 1884: "in sinking a well in the Ganges for one of the piers of the railway bridge at Benares, when the well was burst by a sudden influx of water from below a bed of clay rising to a greater height than the river water outside the well."[1]

(5) *Borings in other tertiary rocks.*

Boring for oil at Sukkur.

It is only in Gujárát that the tertiary rocks of India have been specially examined in search of water, but it may be mentioned here that one of the deepest borings in this country was sunk in tertiary strata in search of oil at Sukkur. Some of the most successful artesian wells in America, for instance those in Ohio, were originally experimental borings for oil. The Sukkur boring, however, yielded neither oil nor water (excepting a small flow at a depth of 865 feet), but it must be noticed that all the strata encountered were clays and compact limestones of a very impermeable nature. The boring reached a depth of 1,042·6. A complete record has been published by Mr. T. D. La Touche.[2]

As already mentioned in the separate descriptions, it is possible that the Karani, Coconada and Akyab borings although commenced in the alluvium entered tertiary rocks at a certain depth from the surface.

[1] "Further considerations upon Artesian sources in the plains of Upper India. Rec. Geol. Surv. Ind., Vol. XVIII, p. 118.

[2] "Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895." Rec. Geol. Surv. Ind., Vol. XXVIII, pp. 55-59.

(6) *The Gondwanas.*

Structure and composition.

The Gondwana rocks, consisting as they do of alternating strata of sandstone and shale, appear well suited to the formation of artesian reservoirs. The topography is not always sufficiently varied to allow the expectation of a sufficient head to cause an overflow, though this might occur in some of the hilly tracts occupied by the upper Gondwanas, for instance, the Satpura range, of which there exists a geological section published by Mr. Medlicott,[1] showing great masses of various rocks dipping at low angles over large areas, the form of structure best suited for the collection of water in water-tight underground reservoirs. Nevertheless, as mentioned by Mr. Medlicott in his Report on Artesian borings, no overflow has been observed from any of the deep experimental borings put down in the Satpura coal-field during coal explorations at some of the places where the conditions for artesian water appear most favourable, although water under pressure has issued in sufficient amount to necessitate piping down to a considerable depth. The fact that no great difficulties have been met with from the inrush of underground water during mining operations in the lower Gondwanas shows that the strata traversed do not yield water in abundance. It is true that none of these mines are very deep, and it is possible that at greater depths strata might occur forming reservoirs with a larger intake area and an abundant supply of water under pressure.

Experiments in the Satpura Coal-Basin.

A scheme was proposed in 1882 for supplying the town of Raniganj with water from the coal measures. But the proposed well was not to have been artesian: water was to be collected from a permeable bed of inferior coal by means of galleries driven into it, giving a considerable percolating area.

Water-supply of Raniganj.

[1] "Notes on the Satpura Coal-Basin." Mem. Geol. Surv. Ind., Vol. X, pp. 133-188.

Mr. Reader, Mining Specialist of the Geological Survey of India, has brought to my notice an occurrence that took place during some trial borings for coal in the Rampur coal-field in the Central Provinces. A flow of water issued from one of these situated near the Eeb river, forming a jet that rose above the surface. The occurrence was related to Mr. Reader by Messrs. Kilburn & Co., who put down the boring, but it had taken place previous to the detailed examination of the district, and the exact structure of the surrounding rocks has not yet been ascertained.

Boring in the Rampur coal-field.

The following information contained in a letter from Mr. C. Matthews, Engineer of the Diamond Drill Agency, Radhnagur, dated 17th August 1900, has been kindly communicated by Messrs. Kilburn & Co.: "Water commenced flowing from bore-hole at Dhoramanda at about 80 feet from surface, and greatly increased at depth of 120 feet, after passing through coarse grey free sandstone, and the water kept flowing continuously at about 600 gallons per hour, or equal to a discharge of a 1¼" bore piping. In a trial to note to what height the water would rise above the bore-hole, two lengths of boring rods were connected to pulley head, and water rose full 20 feet height and kept overflowing. When the height was increased to 30 feet the water did not overflow. But this may be due to the water escaping below the casing tubes and working through the porous loose soil, and consequently the water could not accumulate as fast as it escaped through the soil, to gain sufficient head to overflow above 20 feet.

"The diameter of hole is about 4" to a depth of 40 feet, and from that depth to 830 feet it is 2" practically. The top of bore-hole was lined to a depth of 26 feet from surface, and below this depth the stratum was firm to withstand the sides from erosion or falling in.

"The position of bore-hole is in a valley between two ranges of hills, the height of the hills would not appear more than 80 to 130 feet above that of the bore-hole.

"The bed of stream is about 20 feet below bore-hole surface, and is running about 200 feet from nearest point of bore, the width would be about 30 to 40 feet in part. About 380 to 400 feet from surface, I noticed a greater volume of water running over the bore equal to nearly 2,000 gallons or thereabout, and I do not think that the flow of water got diminished. The lining tubes have been withdrawn from hole."

Experimental borings in the coal-fields.

The Records of the Geological Survey contain accounts of a great many of these sets of trial borings for coal. In one case, in a description of an exploration in the Chhattisgarh coal-fields, mention is made of a boring where a sheet of water was struck at a depth of 14 feet, and gave a permanent flow at the surface.[1] Judging from the description, however, the site is in the low ground on the banks of a river, and as the water was tapped at such a small depth, it was no doubt in close connection with the ground-water at no great distance, the case being analogous to that of the Mahi river in Gujárát, or of the Ganges bridge at Benares.

Along the east coast of the Peninsula there are several areas of upper Gondwanas whose strata dip at low angles towards the sea-coast, and which appear therefore suited to the existence of artesian conditions. Several experiments have been made to test these localities, but with small success so far. Such is the boring

Boring at Place's Garden, near Madras.

at Place's Garden, Kilacheri, in the Chingleput district near Madras. The work was originally undertaken by the Reverend S. Dominic, Superior of the Monastery at Place's Garden, and, on account of the great interest attached to the experiment, Government aid was granted on various occasions to enable the work to be pursued. On being consulted by the Government of Madras in 1891, when the boring was nearly 300 feet deep, Mr. Foote stated that he had reason to believe that a

[1] "Boring exploration in the Chhattisgarh Coal-fields," by William King. Rec. Geol. Surv. Ind., Vol. XIX, p. 229.

water-bearing stratum would be pierced near the base of the series where it rests on gneiss. The pressure might not be sufficient perhaps to cause a flow of water, but it would be within easy reach of pumps.

Sections situated a few miles north and north-west of the artesian boring show that the basement beds of the Gondwanas consist of a considerable thickness of permeable felspathic grit. The boring runs through a great thickness of black and dark grey carbonaceous clays which probably overlie that sandstone.

The Gondwana rocks exposed to the eastward and northward have been described by Mr. Foote.[1] They belong to the upper Gondwana stage. The rocks exposed belong mainly to the upper part of the series and consist of light-coloured shales, clays and sandstones. But in the boring they are found to be underlaid by the above mentioned dark grey and black carbonaceous shales; in fact, it was through the boring that the existence of these dark clays first came to be known.

At the date of Mr. Foote's visit the boring had been carried through a considerable thickness of these impervious clays. It had been stopped for want of funds, but Mr. Foote considered that the water-bearing stratum was not far off, and that the boring should be continued until water is struck, or until the underlying gneiss is reached. Moreover, Mr. Foote pointed out that some of the dark carbonaceous clays are bituminous, and that, even if the boring were unsuccessful from the point of view of water, yet it might reveal the existence of coal seams or of bituminous shales worth distilling, or of valuable fire-clay. It would be, besides, of great scientific interest.

Since Mr. Foote's visit the boring has been deepened over 100 feet: in October 1899 it had reached a depth of 430 feet. Yet, the felspathic grit has not been reached, although a small band of

[1] "On the Geology of parts of the Madras and North Arcot districts lying north of the Palar River." Mem. Geol. Surv. Ind., Vol. X, Part I.

sandstone four inches thick has been met with at a depth of 344 feet, and a second one 2 feet 2½ inches thick, at a depth of 359 feet. In a letter dated 19th November 1892, addressed to the Government of Madras, Dr. King recommended that the boring be carried down to a depth of at least 450 feet.

Boring at Ellore.

Rocks of upper Gondwana age are found also near the mouths of the Godavari, and they have yielded water at Ellore in a boring which is still in progress at the present time. The strata dip towards the sea-coast to the south-east, in which direction they sink beneath volcanic rocks, of the age of the "Deccan Trap," Rajahmundry beds of the age of the Cuddalore sandstones, and finally alluvium. The upper Gondwanas here consist principally of sandstones, an upper series, the Tripety sandstones, and a lower one, the Golapilly beds. A series consisting principally of clays, the Kagavapuram shales, intervene between the two sandstone groups. It has no great thickness but from its impermeable nature it provides a confining stratum to the water contained in the Golapilly sandstone, the other requisites for artesian action being provided by the lie of the stratification.[1] It is difficult to decide, without having seen any specimens, how much of the alternating sands and clays met with up to a considerable depth in the Ellore boring may belong to the alluvium, to the Rajahmundry beds or to the Tripety sandstones. Some specimens from a depth of 367 feet were forwarded to the Geological Survey Office and examined by Mr. Holland who identified them as probably belonging to the Ragavapuram shales. The circumstances therefore seemed favourable, on account of the probable proximity of the underlying Golapilly sands. In a letter, dated 13th June 1900, Mr. Holland had just expressed his opinion as to the advisability of continuing the boring, when a communication forwarded on the same

[1] The geology of this country has been described by Dr. King in his paper on "the upper Gondwanas and other formations of the coastal region of the Godavari district." Mem. Geol. Surv. Ind., Vol. XVI, p. 195.

date by the Engineer-in-Chief of the East Coast Railway announced that the boring had struck sand at a depth of 390 feet, and that water had risen in the tube to within 16 feet of the ground-level. The same communication contains a section of the boring up to a depth of 384 feet, from which the following record is reproduced:—

Section of Artesian Well-boring at Ellore.

Number of stratum.	Thickness of stratum.	Total depth from ground-level.	Description of strata.
	Feet.	Feet.	
1	10	10	Black cotton soil.
2	10	20	Black clay hard and stiff. (Water level at 15 ft.)
3	10	30	Red clay.
4	20	50	Brown clay.
5	10	60	Brown clay and sand.
6	10	70	Nodular limestone and clay.
7	10	80	Yellow clay.
8	10	90	Brown clay interspersed with gravel.
9	40	130	Grey clay and lime nodules.
10	20	150	Red and yellow clay.
11	10	160	Grey and yellow clay.
12	10	170	Grey clay.
13	10	180	Yellow clay with kankar.
14	10	190	Decomposed yellow sandstone and clay.
15	10	200	Red and yellow clay.
16	10	210	Brown and yellow clay with kankar.
17	10	220	Yellow and grey clay with kankar.
18	10	230	Yellow and red clay with kankar.
19	10	240	Yellow and red clay and decomposed rock.

Section of Artesian Well-boring at Ellore—contd.

Number of stratum.	Thickness of stratum.	Total depth from ground-level.	Description of strata.
	Feet.	Feet.	
20	10	250	White and red clay with nodules of laterite.
21	10	260	Yellow and grey hard stiff soil.
22	10	270	White sandy clay interspersed with large shingles.
23	10	280	White and brown clay interspersed with minute pebbles.
24	10	290	Yellow clay.
25	10	300	Light grey sandy clay.
26	10	310	Yellow streaky clay.
27	9	319	Yellow clay, light yellow sandy clay.
28	1	320	More or less pure sand, large grained.
29	10	330	Very hard stiff clay, yellow and white streaky clay.
30	10	340	Decomposed rock and clay. Decomposed streaky sandstone clay. White clay streaked yellow. Yellow, white and red streaky clay.
31	10	350	Yellow and white clay. Yellow and white chalky clay. White clay. Purple and brown clay. } Resembling chalk.
32	10	360	Purple and yellow clay. Purple and white clay. } Resembling chalk.
33	7	367	Crimson clay (decomposed laterite) ; yellow and purple clay.
34	3	370	Pink clay with some yellow and white purple clay. } Resembling chalk.
35	7	377	Magenta and purple clay. Stiff clay and purple clay. } Resembling chalk.
36	3	380	Yellow clay mixed with grey. } Resembling chalk.
37	4	384	Light pink clay mixed with sand.

(7) *The Vindhyans.*

The Vindhyans, like the Gondwanas, consist largely of alternating layers of sandstone and shales, in addition to which, however, there

are great masses of limestone. The strata are older than those that make up the Gondwanas, and the sandstones are very much more indurated. This must affect their permeability to a considerable degree, but whether so much as to prevent any decided flow, has never been tested.

Structure apparently favourable.

If the diminution of porosity caused by the induration of the sandstone does not oppose too great an obstacle to the flow of water, the structure is in many places an ideal one for artesian conditions. For instance, the great spread of Vindhyans in Central India might be compared to a series of shallow saucers of varying composition and of gradually decreasing size placed one upon the other. If the materials composing any of those layers are fairly permeable, there must be many places in the Saugor district, and in Rewah, Bhopal, Gwalior, and other States and Provinces of Central India where the sinking of artesian wells has every chance of success. One experiment made at a suitably chosen place might at once decide the question for a very large area. The testimony of the only boring that penetrated into this formation, the one at Agra, is inconclusive: whether the flow of mineral water that issued from the boring proceeded from the Vindhyans or not, the locality is at the edge of the formation, and the boring did not traverse any of those great alternations of shales and sandstones such as would be met with at suitable localities, and which, by their differences in permeability, might be expected to provide the water-tight layers necessary for confining an artesian reservoir.

A basin of very similar strata occupies considerable portions of Chhattisgarh. No experiments have been attempted there, but Mr. Medlicott, without giving any very decisive opinion, thought that the circumstances were fairly favourable.

The Kadapahs and Karnuls of the Deccan are not unlike the Vindhyans, but they are generally more disturbed.

(8) *The Deccan Trap.*

Need of more accurate information.

A system of rocks whose capabilities as water-bearing strata call for further research is the volcanic series known as the "Deccan Trap." The immense area occupied by that formation has almost entirely escaped geological investigation. The series consists largely of basalt, a rock of highly impermeable texture, but it is not known to what extent the existence of fissures and caverns may not affect its capacity in that respect. In some parts of the Bombay Presidency wells have been known to derive an abundant supply of water from fissures in the basalt.

Composition.

Moreover, the formation does not consist entirely of basalt: in some parts the sheets of basaltic lava are interbedded with great masses of tuff of more or less open texture. During intervals between the volcanic eruptions fresh water lakes were formed, in which sediments, the so called "intertrappeans," were deposited. Some of them are very compact limestones, but others are sands of loose texture. All these fragmentary rocks, tuffs, and intertrappeans might occur so placed as to form artesian reservoirs. But in our ignorance of the geological details of the formation, the existence of such reservoirs can only be indicated as a bare possibility without any reference to particular localities.

Structure.

In the western portion of their outcrop, near Bombay or in Gujárát and Kathiawar, these rocks have undergone a certain amount of disturbance. But in all other parts of the area occupied by the Deccan trap, the rocks are quite undisturbed and almost horizontal. Perfect horizontality of stratification would be incompatible with the existence of an artesian reservoir, unless accompanied (as it is sometimes) by irregularities of water-bearing capacity at various places. But it stands to reason that the horizontality of the strata that compose the

"trap" formation is only apparent. Basalt is not formed on the sea-floor by some mysterious process of crystallisation as was thought by the adepts of the school of the "Neptunists" during the early part of the century, but it issues in a semi-fluid condition out of volcanic vents. Lavas relatively poor in silica and rich in iron, "basic" lavas in fact, like those that constitute such a large proportion of the Deccan trap formation, flow much more easily than do the more siliceous or "acid" ones. Yet their flow is not comparable with that of water, and when they solidify they are still in an inclined position, however slightly so. The huge area covered by the products of the eruptions whose accumulated masses probably rose into high mountains, has now been levelled to the shape of a plateau, and the low angles of dip of the overlapping sheets of lava get lost in the irregularities produced by denudation. The formation is practically horizontal when considered as one mass, and has only been studied as such. But there is no doubt that a more thorough examination will reveal great complexity of detail notwithstanding the uniformity of the general features, and it is by no means unlikely that it may bring to light the existence of artesian reservoirs of a very perfect character, if of limited extent.

Experiment at Mhow in Central India.

An experiment which seemed very promising was undertaken in 1884 at Mhow in Central India. In June 1884, a well was sunk at the engine shed of the Bombay, Baroda and Central India Railway. The junction of the "moorrum," or decomposed basalt, and of the hard rock is 35 feet below the ground surface. "Moorrum" is the name given to a peculiar form of surface decomposition of the basalt: it is permeable, and from it the surface wells of a large portion of the Deccan and of Malwa derive their supply. In the present instance, a certain amount of water issued at the junction of the "moorrum" with the underlying hard rock. The well was deepened to 90 feet below the surface of the ground without coming across any springs. A 2½ inch bore was put down at the bottom up to 13 feet, which in

96 hours filled the well up to 41 feet 6 inches from the surface of the ground. The diameter of the well was 25 feet, and the spring had delivered 49,459 gallons.

The locality does not seem to be in a very favourable situation, for it is only a short way north of the scarped face of the Vindhyan range.[1] Thus the surface of the ground at the locality where the well was sunk is at a higher level than the neighbouring region at a short distance further south, and it could not be expected under such conditions that the well would overflow. The following views were expressed by Mr. Medlicott on the subject of this experiment: "It would seem impossible for a sufficient head of water to accumulate for a surface delivery at Mhow. On the other hand, trappean rocks are very retentive of water and thus favourable for constancy of supply. The streams in such a country carry water much later than in similar ground formed of other rocks. This consideration would be in favour of a supply by deep wells, of which the engine shed well gives a very promising example." It is to be regretted that this experiment has remained an isolated one so far as is known.

Besides the possible existence of reservoirs formed by loose textured tuffs and intertrappean sandstones, or by fissures and caverns in the basalt itself, it must be kept in mind that the products of the eruptions have overwhelmed a very irregular ancient land surface.

Irregularity of the floor underlying the formation.

In many places the decomposed rock surfaces composing this old land area and the ancient soil must form a more or less porous layer at the base of the volcanic formation, and, if the shape of this underlying surface could be known, it would be possible to select some likely places for experimental borings, as the porous layer might be locally disposed in such

[1] The name "Vindhyan" has been applied by the Geological Survey to a peculiar group of strata which have already been spoken of; but in a geographical sense the name applies to the rectilinear scarp north of the valleys of the Nerbudda and Son, the eastern part of which consists of "Vindhyan sandstones," but which, further west, is composed only of volcanic rocks.

a manner as to form underground reservoirs. In the Deccan the thickness of accumulated lavas and tuffs is so great that the underlying rocks are concealed over considerable areas, and no accurate knowledge of the underlying surface could be arrived at except by a large series of experimental borings involving an expenditure out of all proportion with any results that could be reasonably predicted. But in Central India, where the thickness is not so great, the underlying rock shows itself in many places, and if these inliers of the older formations were mapped and their structure examined, it would be possible to arrive at a very fair idea of the shape of the surface upon which the strata of volcanic rocks are resting. I was able to ascertain this circumstance during a rapid inspection, which I made in 1898, of a part of Bhopal occupied by that formation: small mounds of Vindhyan sandstone stand out here and there above the almost level expanse of basalt. These are the tops of hill ranges buried beneath the solidified flows of volcanic lava. Before the lavas were poured over them, the Vindhyans were acted upon by the agencies of denudation just in the same manner as at the present day, and the topographical features thus produced bear a very distinct relation to their stratigraphy: once the lie of the different bands of strata composing them is revealed by the study of those inliers, it becomes easy to make out the shape of the surface with sufficient approximation, and thus decide on a choice of the places where water occurring at the junction of that old land surface and the overlying rock would be most likely to rise at or near the surface through a boring.

(9) *Other rocks.*

The alluvium, the tertiary, the Gondwanas, the Vindhyans and allied formations, and the Deccan trap are the principal formations within which there can be any likelihood of artesian water being found, although even in these rocks the chances are very uncertain. In addition to these formations, there are enormous areas occupied

by slates and metamorphic rocks, and by schists and gneisses, some of which have a more or less granitic tendency. Their highly crystalline and compact texture is incompatible with the existence of any great store of water. The very rare cases in which a flow of water has been obtained from such rocks are due to exceptionally disposed fissures. Not only can the possibility of such an occurrence be only very rare, but such cases could never be predicted from observations made at the surface. All the areas occupied by these rocks should be left out of consideration in the problem of artesian water-supply. In 1884 a boring was sunk in rocks of this class at Vizianagram, notwithstanding the adverse circumstances of the case, and after being carried to a depth of 350 feet, it failed to procure any supply of water.[1]

Boring at Vizianagram.

(10) *Conclusion.*

In conclusion, it may be stated that the possibilities of artesian supply in India are not fully understood and have been very imperfectly tested. But even if they were much greater than outward appearances would lead us to infer, still it would be a great mistake to think that they could be of the slightest utility in any extensive scheme of irrigation. On the other hand, leaving out of question the problem of irrigation on a large scale, there are many minor uses to which artesian water can be put to with great advantage, and viewed in that light, the subject is certainly deserving of attention and probably capable of development.

[1] This boring is mentioned in the "Geological sketch of the Vizagapatam District, Madras," by William King. Rec. Geol. Surv. Ind., Vol. XIX, p. 143.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi *vid* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta pargenas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the microscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, South-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz-Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the district of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the Records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica-traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan (with a map). Report of a Journey through India in the winter of 1888-89, by Dr. Johannes Walther, translated from the German, by R. Bruce Foote. On the Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills (with 3 plans). Further Note on Indian Steatite. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt Marl (with five plates). On Veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sherâni country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of the

Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle) Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* Dr. P. Martin Duncan. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on Rocks from the Salt-range, Punjab (with two plates).

Vol. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Subrecent *and* Recent Deposits *of the valley plains of* Quetta, Pishin and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

Part 2.—Geology *of the* Saféd Kóh (with 2 plates of sections). Report *on a* Survey *of the* Jherria Coal field (with a map and 3 section plates) (*out of print.*)

Part 3.—*Note on the* Locality *of* Indian Tscheffkinite. Geological Sketch *of the* country north of Bhamo. Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma. Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District. *On the* Occurrence *of* Riebeckite *in* India. Coal *on the* Great Tenasserim River, Mergui District, Lower Burma.

Part 4.—Report *on the* Oil Springs *at* Moghal Kot *in the* Shirani Hills (with 2 plates). Second Note *on* Mineral Oil *from the* Suleiman Hills. *On a* New Fossil, Amber-like Resin *occurring in* Burma. Preliminary notice *on the* Triassic Deposits *of the* Salt-range.

Vol. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

Part 2.—Notes *on the* earthquake *in* Baluchistán *on the* 20th December 1892 (with 2 plates). Further Note *on* Burmite, *a new amber-like fossil resin from* Upper Burma. Note *on the* Alluvial deposits *and* Subterranean water-supply *of* Rangoon (with a map).

Part 3.—On the Geology *of the* Sherani Hills (with maps and plates). On Carboniferous Fossils *from* Tenasserim (with 1 plate). *On* a deep Boring *at* Chandernagore. Note *on* Granite *in the districts of* Tavoy *and* Mergui (with a plate).

Part 4.—*On the* Geology *of the country between the* Chappar Rift *and* Harnai *in* Baluchistán (with map and 3 plates). Notes *on the* Geology *of a part of the* Tenasserim Valley *with special reference to the* Tendau-Kamapying Coal-field (with two maps). *On a* Magnetite *from the* Madras Presidency containing Manganese *and* Alumina. *On* Hislopite (Haughton) (with a plate).

Vol. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of petroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landslip, Garhwal (with 5 plates and 2 maps).

Part 3.—*On the* Cambrian Formation *of the* Eastern Salt-range (with a plate). The Giridih (Karharbari) Coal-field, *with notes on the* labour and methods of working (with 2 maps and 8 plates of sections). *On the* Occurrence of Chipped (?) Flints *in the* Upper Miocene of Burma (with a plate). Note *on the* Occurrence *of* Velates Schmideliana, Chemn., *and* Provelates grandis, Sow. *sp., in the* Tertiary Formation *of* India *and* Burma (with plates).

Part 4.—Note on the Geology of Wuntho *in* Upper Burma (with a map). Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán. *On* Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal. *On a* Mica-Hypersthene-Hornblende-Peridotite *in Bengal.*

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry. Some* early allusions *to* Barren Island; *with a few remarks thereon.* Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks.*

Part 2.—On the importance of Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times. *Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895. The development and Subdivision of the Tertiary system in Burma.*

Part 3.—On the Jadeite *and other rocks, from* Tammaw *in* Upper Burma. *On the* Geology *of the* Tochi Valley. *On the* existence *of* Lower Gondwanas *in* Argentina.

Part 4.—On the Igneous Rocks *of the* Giridih (Kurhurbaree) Coal-field *and their* Contact Effects. *On* some outliers *of the* Vindhyan system south *of the* Sone and their relation *to the* so-called Lower Vindhyans. *Notes on a* portion *of the* Lower Vindhyan area *of the* Sone Valley. *Note on* Dr. Fritz Noetling's paper *on the Tertiary system in Burma, in the Records of the Geological Survey of India for 1895, Part 2.*

Vol. XXIX, 1896.

Part 1.—Annual report for 1895. *On the Acicular inclusions in Indian Garnets. On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks* (with 1 plate).

Part 2.—Notes on the Ultra-basic rocks *and* derived minerals *of the* Chalk (Magnesite) hills, *and other localities near* Salem, Madras (with 2—6 plates). *Preliminary notes on some* Corundum localities *in the* Salem and Coimbatore districts, Madras (with 7—9 plates). *On the occurrence of* Corundum *and* Kyanite *in the* Manbhum district, Bengal. *On the papers by* Dr. Kossmat and Dr. Kurtz, *and on the ancient Geography of "Gondwana-land." Note from the Geological Survey of India.*

Part 3.—On some Igneous Rocks *from the* Tochi Valley. *Notes from the Geological Survey of India.*

Part 4.—Report *on the* Steatite mines, Minbu District, Burma. Further notes *on the* Lower Vindhyan (Sub-Kaimur) area *of the* Sone Valley, Rewah. *Notes from the Geological Survey of India.*

Vol. XXX, 1897.

Part 1.—Annual Report for 1896. *On* some Norite *and* associated Basic Dykes *and* Lava-flows *in* Southern India (with plates I to II). *The reference of the genus* Vertebraria. *On a* Plant of Glossopteris with part of the rhisome attached, *and on the* structure of Vertebraria (with plates III to V).

Part 2.—The Cretaceous Deposits of Pondicherri (with plates VI to X). *Notes from the Geological Survey of India.*

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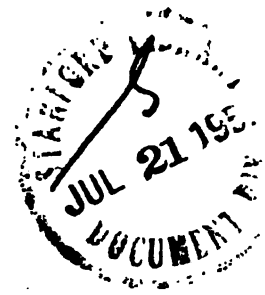

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Part 3.—The Mohpani coal-field. On the lead-ore at Slimanabad, Jabalpur district. On the occurrence of coal east of Chhatisgarh in the country between Bilaspur and Ranchi. On petroleum in Burma. On the petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. On the occurrence of argentiferous galena and copper in the district of Manbhum, S. W. Frontier of Bengal. Assays of iron ores.

Part 4.—On the geology of Mount Tilla, in the Punjab. The copper deposits of Dalbhum and Singbhum: 1.—The copper mines of Singbhum: 2.—On the copper of Dalbhum and Singbhum. Meteorites.

VOL. IV, 1871.

Part 1.—Annual report for 1870. Enquiry into an alleged discovery of coal near Gooty, and of the indications of coal in the Cuddapah district. Mineral statistics of the Kumaon division.

Part 2.—The axial group in Western Prome. Geological structure of the Southern Konkan. On the supposed occurrence of native antimony in the Straits Settlements. On the composition of a deposit in the boilers of steam-engines at Raniganj. On the plant-bearing sandstones of the Godavari valley, on the southern extension of rocks belonging to the Kamthi group to the neighbourhood of Ellore and Rajamandri, and on the possible occurrence of coal in the same direction.

Part 3.—The progress and results of borings for coal in the Godavari valley near Dumaguden and Bhadrachalam. On the Narbada coal-basin. Sketch of the geology of the Central Provinces. Additional note on the plant-bearing sandstones of the Godaveri valley.

Part 4.—The ammonite fauna of Kutch. The Raigur and Hengir (Gangpur) Coal-field. Description of the sandstones in the neighbourhood of the first barrier on the Godavari, and in the country between the Godavari and Ellore.

Vol. V, 1872.

Part 1.—Annual report for 1871. Rough section showing the relations of the rocks near Murree (Mari), Punjab. Mineralogical notes on the gneiss of South Mirzapur and adjoining country. Description of the sandstones in the neighbourhood of the first barrier on the Godavari, and in the country between the Godavari and Ellore.

Part 2.—On the geological formation seen along the coasts of Beluchistan and Persia from Karachi to the head of the Persian Gulf, and on some of the Gulf Islands. On a traverse of parts of the Kummummet and Hanamconda districts in the Nizam's Dominions. The geology of Orissa. On a new coal-field in the south-eastern part of the Hyderabad (Deccan) territory.

Part 3.—On Maskat and Massandim on the east coast of Arabia. An example of local jointing. On the axial group of Western Prome. On the geology of the Bombay Presidency.

Part 4.—On exploration for coal in the northern region of the Satpura basin. On the value of the evidence afforded by raised oyster banks on the coasts of India, in estimating the amount of elevation indicated thereby. On a possible field of coal-measures in the Godavari district, Madras Presidency. On the lameta or infra-trappean formation of Central India. On some recently discovered petroleum localities in Pegu. Correction regarding the supposed eozoonal limestone of Yellam Bile.

Vol. VI, 1873.

Part 1.—Annual report for 1872. The geology of the North-West Provinces.

Part 2.—The Bisrampur coal-field. Mineralogical notes on the gneiss of South Mirzapur and adjoining country.

Part 3.—Notes on a celt found by Mr. Hacket in the ossiferous deposits of Narbada valley (Pliocene of Falconer): on the age of the deposits, and on the associated shells. On the Barakars (coal-measures) in the Beddadanole field, Godavari district. On the geology of parts of the Upper Punjab. Coal in India. The salt-springs of Pegu.

Part 4.—On some of the iron deposits of Chanda (Central Provinces), Barren Islands and Narkondam. Stray notes on the metalliferous resources of British Burma.

Vol. VII, 1874.

Part 1.—Annual report for 1873. On the geological structure of the hill ranges between the Indus valley in Ladak and Shah-i-Dula on the frontier of Yarkand territory. On some of the iron ores of Kumaon. On the raw materials for iron-smelting in the Raniganj field. On the habitat in India of the elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

Part 2.—Geological notes on the route traversed by the Yarkand Embassy from Shah-i-Dula to Yarkhand and Kashgar. On the occurrence of jade in the Karakas valley, on the southern borders of Turkistan. Notes from the Eastern Himalaya. Petroleum in Assam. Coal in the Garo Hills. On the discovery of a new locality for copper in the Narbada valley. Potash-salt from East India. On the Geology of the neighbourhood of Mari hill station in the Punjab.

Part 3.—Geological observations made on a visit to the Chaderkul, Thian Shan range. On the former extension of glaciers within the Kangra district. On the building and ornamental stones of India. Second note on the materials for iron manufacture in the Raniganj coal-field. Manganese ore in the Wardha coal-field.

Part 4.—The auriferous rocks of the Dhambal hills, Dharwar district. Remarks on certain considerations adduced by Falconer in support of the antiquity of the human race in India. Geological notes made on a visit to the coal recently discovered in the country of the Luni Pathans, south-east corner of Afghanistan. Note on the progress of geological investigation in the Godavari district, Madras Presidency. Notes upon the subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1.—Annual report for 1874. The Altum-Artush considered from a geological point of view. On the evidences of 'ground-ice' in tropical India, during the Talchir period. Trials of Raniganj fire-bricks.

Part 2 (out of print).—On the gold-fields of south-east Wynaad, Madras Presidency. Geological notes on the Khareean hills in the Upper Punjab. On water-bearing strata of the Surat district. Sketch of the geology of Scindia's territories.

Part 3.—The Shahpur coal-field, with notice of coal explorations in the Narbada region. Note on coal recently found near Moflong, Khasia Hills.

Part 4.—Note on the geology of Nepal. The Raigarh and Hingir coal-fields.

Vol. IX, 1876.

Part 1 (out of print).—Annual report for 1875. On the geology of Sind.

Part 2.—The retirement of Dr. Oldham. On the age of some fossil floras in India. Description of a cranium of Stegodon Ganesa, with notes on the sub-genus and allied forms. Note upon the Sub-Himalayan series in the Jamu (Jummoo) Hills.

Part 3.—On the age of some fossil floras in India. On the geological age of certain groups comprised in the Gondwana series of India, and on the evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. On the relations of the fossiliferous strata at Maleri and Kota, near Sironcha, C. P. On the fossil mammalian faunæ of India and Burma.

Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Occurrence of Plesiosaurus in India. On the geology of the Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1.—Annual report for 1876. Geological notes on the Great Indian Desert between Sind and Rajputana. On the occurrence of the cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. On Estheria in the Gondwana formation. Notices of new and other vertebrata from Indian tertiary and secondary rocks. Description of a new Emydine from the upper tertiaries of the Northern Punjab. Observations on underground temperature.

Part 2.—On the rocks of the Lower Godavari. On the 'Atgarh Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Arvali series in North-eastern Rajputana. Borings for coal in India. On the geology of India.

Part 3.—On the tertiary zone and underlying rocks in the North-west Punjab. On fossil floras in India. On the occurrence of erratics in the Potwar. On recent coal explorations in the Darjiling district. Limestones in the neighbourhood of Barakar. On some forms of blowing-machine used by the smiths of Upper Assam. Analyses of Raniganj coals.

Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Eryon Comp. Barrovensis,' McCoy, from the Sripermatur group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the North-west Punjab. Note on the genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks, &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a trip over the Milam Pass, Kumaun. The mud volcanoes of Ramri and Cheduba. On the mineral resources of Ramri, Cheduba, and the adjacent islands.

MEMOIRS

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VOL. XXXII, PART 2.

REPORT ON THE RAMPUR COAL-FIELD, *by* G. F. READER,
Mining Specialist, Geological Survey of India.

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CONTENTS.

CHAPTER I.—Introduction.
„ II.—Geology.
„ III.—Coal Explorations.
CHAPTER IV.—Workable thicknesses of coal proved.
Appendix.

CHAPTER I.

INTRODUCTION.

When drawing up the Progress Report in camp on this field, time did not permit of my discussing all the data known and I confined myself directly to the main object of this survey, namely, "Is there any likelihood of finding a workable coal-seam?" Having now had a full opportunity of perusing all the papers relating to the various, apparently independent, explorations in this area, I am enabled to discuss in greater detail all the facts known which tend to answer that question, to show what still remains to be done and how in my opinion a conclusion can most speedily and effectively be arrived at.

Position and general Physical Features.

The part of the coal-field here described lies in the Central Provinces, about 22 miles N. N. W. of Sambalpur, in the bay formed by the junction of the Lillari nala with the Eeb river; its area is roughly 50 square miles.

The general level of the area is about 750 feet above sea-level. Apart from the Bilpahari range of hills to the north which rise some 400 to 500 feet higher and form a boundary to the Barakar rocks, and the hill, called Barakar on sketch-plan, to the south of Kiraruma, which rises about 100 feet above this average level, and perhaps the Luchkura range and Jamwapali hill, there is no very great departure from this level. Nevertheless the country is by no means of even gradient, for rugged little hills covered with laterite and thick jungle occur at every turn, and make the work of surface exploration a difficult one.

The symmetry of the sketch-plan attached is remarkable. The Eeb river and Lillari nala form a semi-circular curve having a centre situated somewhere in the Bilpahari range from which their tributaries evenly distributed appear to radiate. The rugged little hills above-mentioned, which form the watersheds for these tributaries, also possess a somewhat palmate arrangement striking off from the Bilpahari hills and forming, as it were, the framework of the area. This symmetry is enhanced by the Bengal-Nagpur Railway line which forms a more or less inner concentric curve.

Previous writers.

The area has already been treated on by Dr. Ball, in the Records of the Geological Survey of India, Vol. viii, Part 4, Dr. King, in the Records of the Geological Survey of India, Vols. xvii-3, xviii-4, xix-4, and xx-4, and by Mr. F. H. Smith, Deputy Superintendent of the Geological Survey of India. The former discussed it from a stratigraphical standpoint simply; the latter with a view to discovering its resources as a workable coal area. Dr. King's coal explorations were, however, very general—extending over the whole of the Chhattisgarh coal-fields. The present exploration is confined to a much smaller area and partakes more of the nature of a detailed Geological Survey.

Previous history.

The proposed construction of the Bengal-Nagpur Railway line through this known Barakar area and the great distance to the nearest coal supply, Warora—

the average lead from which source is 232 miles—brought the question of the coal resources of this field into prominence.

One thick band of upwards of 40 feet of carbonaceous and grey shales associated with some thin layers of coal near Durlipali, and several thin coal-seams near Bonjari and Khaliabahal, had long been known to exist in the Lillari nala. Dr. King was deputed to examine and report upon the prospects of this field as a staple source of coal supply. Under his directions ten boreholes and one shaft were put down which gave such poor results that no further action was taken in prospecting for coal until the discovery of a seam of coal under the site of the Eeb bridge (see Plan) on the Bengal-Nagpur Railway. On this discovery a grant was made by Government to the Bengal-Nagpur Railway Company to explore the coal area around Telanpali. In this exploration five boreholes and one shaft were put down. The general result was not encouraging, but on the report being submitted to Mr. Griesbach, Director of the Geological Survey of India, he, not being satisfied that the lower measures of Barakars which usually contain the best coal-seams had been sufficiently proved, advised the deepening of borehole No. 4 (near Kodapali—see Map) until the undoubted Talchir rocks were struck. In pursuance of this opinion Government sanctioned the work of carrying the boring to a depth of 600 feet. According to the boring record a seam of coal 7′9″ thick, with a 6″ band of stony shale in the middle, was struck at a depth of 347 feet, then for a hundred feet a remarkable succession of alternating bands of thin coal and shale were encountered, and the remaining 38 feet passed through fine sandstone, the hole being stopped at a depth of 485 feet in this stone before reaching the Talchirs. This boring result was deemed by Mr. Griesbach sufficiently encouraging to advise going on with the work for another 100 feet or so until the undoubted Talchir rocks were struck, unless the crystalline rocks were struck at a lesser depth. The boring contractors, however, said that the cost of drilling to this depth would be very great and Mr. F. H. Smith of the Geological Survey of India was deputed to visit the spot to ascertain whether it could be regarded

as reasonably certain that two borings to a depth of 500 feet would give the same information as one to a depth of 1,000 feet, and if strong evidence existed in favour of this conclusion, to mark the exact position at which the second borehole should be drilled with reference to the one under discussion. The examination did not answer this question and it was considered a better plan to select a site near Dhoramuda practically at the top of the Barakars and bore through the whole thickness of the Barakars on to the undoubted Talchirs or metamorphics, as the case might be, it being then estimated that the total depth would probably be below 800 feet. A borehole was put down here to a depth of 828 feet and passed through several shaly coal-seams finally stopping in the zone of Barakar rocks exposed, I think in the Lillari nala near Piplimal and several hundred feet above the top, geologically speaking, of the Kodapali (No. 4) borehole. It will therefore be seen that the lower measures of the Barakars have not been proved as was intended.

Dhoramuda borehole.

Before setting out for this area I was supplied with the one inch to a mile topographical map. It was my intention to put this map on a larger scale to make a working plan. Fortunately time did not permit of my doing this in Calcutta, for in the course of preliminary work in the field I was forced to the conclusion that the map was absolutely unreliable and not sufficiently accurate for recording geological observations.

Topographical Map.

The sketch-plan accompanying this report is one I made myself. It is the result of a loose needle survey made with a 2½ inch prismatic compass held in the hand. The chaining was done by my chaprassis who had never seen a chain before; any inaccuracies it may be found to contain, and I am alive to some, will therefore be readily understood. I did not intend at first to resurvey the whole area, but only the most crucial portions of it and join these on to the Atlas sheet. But when I found the latter so incorrect I was forced to complete the work for the purposes of this report. Only ten weeks were spent in this

Sketch-plan.

area, and before devoting myself to the direct object of this survey I had to turn my attention to these necessary though unforeseen preliminaries.

It will therefore be readily understood that my arrangements for accomplishing the intended object were impeded to a very great extent not more by loss of time than by fresh considerations introduced by the new map.[1]

CHAPTER II.

GEOLOGY.

The distribution of the rock formations is shown on the sketch-plan.

Crystalline rocks.

The crystalline rocks,—chiefly massive gneiss striking generally west-north-west and east-south-east—are colored pink on the plan and form the bottom of a geological basin upon the uneven surfaces of which the Talchir and over-lying rocks were deposited.

Talchir rocks.

The junction of the gneiss and Talchir rocks is plainly seen to the south-east of Kiraruma, where it is traceable for some little distance to the south, and also in the neighbourhood of Putrapali.[2] The only other Talchir metamorphic boundary observed is the one shown to the north of Malda in the Bonum nala. But crystalline fragments are abundant to the west of Balput, and massive gneiss is exposed near the Lillari-Eeb confluence, therefore the boundary must be just north of these points.

[1] As examples of the inaccuracy of the Topographical map I may mention—

	On Topographical sheet.	*Actual distance.*
From Durlipali to Lillari-Eeb junction,	6 miles	3·7 miles.
From Durlipali to Bonjari-Sumra Road,	2·7 miles	3·6 miles.

The Reb river, south of Rampur (of the Map), is shown to be running due south, whereas it runs west-south-west for two miles. The Bonum nala is most incorrectly delineated.

[2] This last place it was impossible to fix on the Topographical sheet, and as my own rough traverse does not include it, I cannot show its position.

The Talchir-Barakar (Karharburi?) boundary is fairly well-defined in the Lillari nala where the fine-grained greenish grey sandstones of the Talchirs are seen within a few yards of the coarse-grained Barakar sandstones. At this point the Talchirs are striking north-east and dipping 5° to the north-west as also are the overlying Barakars. The next well-defined junction going east is at the Rampur Ghat, on the left bank of the Eeb river, where the Talchir rocks are seen within a short distance of the Barakars. Again a quarter of a mile east of Rampur the Talchir sandstones are observed at no very great distance from the Barakars. East-south-east of the Rampur Ghat about 1¼ miles Talchir shales can be seen dipping in a very irregular manner, the main trend of which is north. I saw no other decisive point to help in further defining this boundary to the south. On the west although not actually seen it is fairly certain that the boundary flanks the left bank of the Bonum nala from the north of Malda to ¼ mile east of Khit where it crosses the nala, sweeps round to the east of Jamwapali hill, swinging round to the west again on the north side of the hill and apparently striking the left bank of the Eeb river just south of Jamwapali village. From this point the boundary would appear to run practically north, striking the right bank of the Eeb river about ¼ mile north of the Gorgor confluence.

There is a good exposure of Talchir sandstones on the left bank of the Eeb opposite Gondgura. Previously a straight boundary line from the east of Jamwapali hill up to this exposure and continued up to the exposure north of the Gorgor has been drawn, but a suspicious looking ridge running along the curve I have defined, seems to lend itself to a more natural delimitation.

It will be observed that Talchirs are also shown on the Plan faulted in to the east of Gondgura; I shall treat on this exposure later in the paper.

So far then it will be seen that the Talchir rocks line the crystalline basin, and that in no instance do the Barakar rocks come in

contact with the Metamorphics except perhaps to the west of Kiraruma where a peak of metamorphic rock is shown.

The thickness of the Talchirs has been estimated at 200 feet; from the few exposures where accurate dips and width of outcrops can be taken it is difficult to arrive at an estimate, but 200 feet is, I think, far too small a figure.

Barakar Group.

No actual contact of Talchirs and Barakars was seen, but in all the cases where Talchirs were exposed in the neighbourhood of Barakars, exposures of the latter where observed were always found to be dipping in the same direction and with practically the same amount of dip as the former.

The Barakars of this area have hitherto been treated in a very general manner, so that a brief record of any well-defined divisions and their distribution will be of use for the purposes of this paper. Four well characterised divisions are noticeable. Beginning at the top these are :—

1° A series of brown-weathering flaggy ferruginous sandstones probably upwards of 100 feet thick, which appear to form a transition series from Barakars to Kamthis.

2° A band of rather fine-grained sandstone of greyish color and about 40 feet thick.

3° The measures composing the greatest part of the thickness of the Barakars, consisting of thin and flaggy sandstones, finely laminated micaceous sandstone, carbonaceous and micaceous sandstone, carbonaceous shales with thin coal bands interspersed and shaly coal-seams.

In this division it is remarkable that the argillaceous, arenaceous and carbonaceous shales predominate in the highest part; that they are present in the same proportion as the sandstones in the middle part, and that the sandstones are largely predominant in the lowest part. This feature very soon strikes one on noting the sections exposed in the Lillari nala. The record of the borehole put down during 1899 near Dhoramuda shews the gradation very well. By divid-

ing the borehole into three equal lengths, the following table shows the gradation :—

	Top Length.	*Middle Length.*	*Bottom Length.*
	%	%	%
Argillaceous, arenaceous shales . . .	60	54	22
Shaly sandstones	40	0	5
Sandstones	0	46	73
	100	100	100

All the boreholes which have been put down to test this Field were started in this division of the Barakars, except perhaps Nos. 1, 2a, 3 and 4 of Dr. King and No. 1 of the Bengal-Nagpur Railway Company. The borehole 828½ feet deep put down near Dhoramuda during 1899 was started near the top of this zone, and I think the one put down during 1896 and 1897 near Kodopali (485′) proves practically the bottom part.

To judge from all the data at present to hand, this zone would appear to be about 1,600 to 1,700 feet thick; it will be seen then that so far as these two boreholes (the Kodopali and Dhoramuda) are concerned there appears still to remain from 500 feet to 600 feet of this division to be proved. Horizontal section A will explain this better.

The sections of the two boreholes above referred to are appended and give in greater detail the succession of the rocks composing this division.

The above division of Barakars includes in its lower part the seam of carbonaceous shale and coal exposed near Durlipali and also "the tesselated ironstone bed" of Dr. Ball exposed a little higher in the section. Where exposed and weathered this ironstone bed is at once recognised. Dr. Ball identified it at Chuakani about five miles north-north-east of Durlipali. The

Durlipali seam is about 500 feet from the bottom of this division.

4° In this, the lowest division of the Barakars, the gradation from shales to sandstones pointed out above appears to be completed; no arenaceous nor argillaceous shales were seen. At the top come conglomerates, resting unconformably on white sandstone—see section B—well exposed near the Eeb bridge both in the river-bed and also on the tops of the hills near Telanpali just north and south of the bridge. Below these come the typical coarse-grained Barakar sandstones towards the top of which a distinct white band of sandstone, about 8 feet thick in places, occurs. These sandstones are 100 feet or more in thickness and form the conspicuous line of hills running from Telanpali on the right bank of the Eeb to Molda on the left bank of the Bonum, ranging from 50 to 100 feet or more in height. The actual sandstones abutting on the Talchirs were nowhere seen, but the lowest observed were coarse-grained though rather fine-bedded and micaceous.

Distribution of the various Zones of Barakars and general considerations.

The boundaries of the areas of the various zones into which I have divided the Barakar rocks are by no means easy to define all over the field. It is possible, however, in some parts to establish approximate boundaries between these zones and by means of these considered in conjunction with data obtained from boreholes, to fix the relative horizons of the various seams proved and to arrive at a fair estimate of the thickness of the Barakars not proved by boreholes.

The sandstone conglomerate zone.

Considering first the lowest or sandstone series and starting in the Lillari on the west, no conglomerates are seen in the neighbourhood nor any of the massive coarse grits typical of this series. The hill between Kiraruma and Durlipali is of a type of sandstone (slightly massive) which can be referred to any of the series. Indeed, were it not that the rocks

were conformably overlying the Talchirs, doubts would arise as to whether these rocks belong to the lowest zone.

Here then it will be seen to be a difficult matter to fix the boundary between the lowest or sandstone conglomerate zone and the next above or sandstone shale zone. For the purposes of this report, however, the boundary may be assumed to cut the Lillari just north of the Barakar hill midway between Durlipali and Kiraruma.

Going further to the east the next most suitable place for consideration of this boundary is between Kodapali and Bundia. Opinion here can be based upon the Kodapali boring on the one side and the assumed presence of Talchirs near Bundia in the Eeb on the other. As regards the borehole, it appears to have been started at about the same horizon as a shale bed supposed to be identifiable with the Durlipali seam. The borehole went down to 485½ feet and at 448 feet left the coal and shaly bed and entered into fine sandstone. This sandstone is probably the bed immediately overlying the conglomerates, and if such be the case marks the line of division between the two series. Allowing 120 feet as the thickness of the lowest series gives it a total of about 600 feet from the top of the borehole to the Talchirs. It is evident then that at about ⅛th of the distance from the Talchirs near Bundia to Kodapali boring the line of division must occur.

Following up the Eeb river from Rampur all the sections seen up to Gondgura belong without doubt to the lowest zone. Half a mile up the river from the Rampur Ghat, however, conglomerates are seen, so that, for our purposes, we may take the line as running just south of Telancachar.

The next point where anything like certainty obtains is near the railway bridge over the Lumchibahal nala where conglomerates are again seen. At Chuakani, a little village ½ mile to the north of Bagmar and ¾ west-north-west of Job, the characteristic tesselated ironstone previously mentioned is seen. From this it follows that the boundary must run on the "crop" side (in this case eastward) of this exposure, the tesselated ironstone belonging to the zone above.

Taking it through Job itself the boundary must run round to the east of the hills north of Chuakani and hence out of our area.

On the plan accompanying this report I have washed the lowest zone dark neutral tint.

Evidence of Fault.

It will at once be noticed that the width of the area shown as occupied by this zone to the east is much greater than that to the south and that such extra width is apparently due to a fault marked as down throwing to the east. The data deemed sufficient to warrant the assumption of a fault as delineated on the map are :—

(*a*) Shales taken to be Talchirs were seen in the Modlia nala dipping west-south-west 15° and apparently cut off from the main bed by an intervening band of Barakars.

(*b*) The white sandstone band, in the lowest zone of Barakars, is seen occupying positions explainable by a fault. For instance, it is seen capping the Jamwapali hill dipping at an angle of 5° to the south-west; nearly a mile due south-west it is seen capping another hill and dipping in the same direction, and also at Telanpali where it has been quarried for bridge-building purposes.

(*c*) At the Eeb bridge a seam of coal has been found underlying a conglomerate band. At three other points marked R^5, R^6, R^7, on the map, coal also underlying a conglomerate bed is observed. It is presumed that these are four exposures of the same seam. Such being the case, it is evident that the outcrop is duplicated.

(*d*) The borehole No. 1 of the Bengal-Nagpur Railway Company's grant put down, under Dr. King's directions, about 150 yards south-south-west of the Eeb bridge, failed to strike coal at a depth of 170 ft., although had the rocks kept their regular dip the Eeb bridge seam should have been struck at a much less depth.

It is upon the above evidence that I have felt myself justified in

tracing the fault as shewn on the map, although in no instance is any actual break of rocks observable. About a mile north of Rampur on the left bank of the Eeb river the rocks are seen to be twisted about in a very strange manner, and again about one mile south-south-east of Rampur near a village called Tangadula, Talchir shales can be seen within a small area dipping in many directions and evidently indicating some disturbance.

If the estimate I have given of the thickness of the lower Barakar series be more or less correct, then from the map it will be seen that a very fair idea as to the amount of throw of the fault can be arrived at. Nevertheless it must be remembered that such thicknesses are only estimated, and moreover that the broad band marked as belonging to the first series of Barakars on the west (or upthrow) side of the fault is so deficient in good sections that only little weight can be given to this as a factor in arriving at the displacement of the rocks.

Sandstone shale zone.

This zone, which comes next above the one just described, extends up the Lillari to Dhoramuda, from whence its boundary sweeps eastward not far to the north of Belpahar station. The hills north of Job belong to this division, since the tesselated sandstone known to occur in its lower half is observed near Job, dipping westward, and somewhere between these hills and the Bilpahari Sitaram hills the divisional line must occur, but the obscurity of physical relations renders further discrimination almost impossible. It may, however, be added that, owing to the high dip and rising ground in the direction of the dip, the width of the zone in the neighbourhood of Job is less than in the Lillari nala.

The two upper zones being economically unimportant are not considered here.

Kamthis.

These rocks which overlie the Barakars consist at their base of brown weathering coarse-grained ferruginous sandstone. Since the conformity or otherwise of these beds with the Barakars is their only feature which is of use for the purposes of this report, their higher beds were not explored.

Conformity.

The relation of the Kamthis to the Barakars has frequently been considered. Dr. Ball favours the idea of unconformity but states that no actual section exhibiting unconformable superposition can be adduced. Dr. King (Rec. Geol. Surv. Ind., Vol. XVIII, pt. 4, pp. 195 and 196) says in reference to this area: "I did not come across any section showing actual contact of the Kamthis on the Barakars, but there always appeared to be perfect conformity between the two." In Rec. Geol. Surv. Ind., Vol. XIX, p. 220, however, Dr. King concurs with Dr. Ball's view of unconformity.

So far as the area here described is concerned, the whole facies of the occurrence of the one formation on the other gives one the idea of perfect conformity and for the purpose of this paper I shall consider the relation as such.

CHAPTER III.

COAL EXPLORATIONS.

The boreholes put down during 1891 and 1892 by the Bengal-Nagpur Railway Company and all put down since are here considered. Boring explorations previous to that date have been treated on by Dr. King in the Rec. Geol. Surv. Ind. The sections of all the boreholes referred to will be found in the appendix.

After the discovery of coal on the site of the Eeb bridge, six boreholes and two small shafts were put down.

No. 1 Borehole was put down 230 yards south-west of the most westerly pier of the Eeb bridge.

No. 2 Borehole and a small shaft near the village of Luchkura.

No. 3 Borehole is described as situated 1½ miles from the west bank of the Eeb river and 2½ miles south of the railway. On reference to the map this will be seen to be incorrect. I am unable therefore to mark the site on the plan annexed.[1]

No. 4 Borehole and a small shaft are near Kodopali.

[1] The sketches to hand purporting to shew the sites of the boreholes are of very little use, being tracings (and sometimes very rough ones) of the topographical map.

No. 5 Borehole near Job, north of the Railway.

No. 6 Borehole near Dhoramuda.

The coal, found at the Eeb bridge (hereinafter called the Eeb river seam) appears to occur only in the eastern half of the river-bed. Accurate levels were taken of the sandstone underlying the seam and indicated a dip of $1\frac{1}{2}^{\circ}$ approximately to the east-north-east; the surrounding rocks however gave a dip of 5° to the south-west. As before stated No. 1 borehole was put down to the south-

No. 1 borehole and the Eeb Bridge Seam.

west of the bridge to prove the extension of the seam in that direction. It was expected that the Eeb river seam would be met with at a depth of 90 ft. at most, but although the borehole was carried to 170 feet, no trace of coal was found.

In a report drawn up in 1892 on this exploration Mr. C. J. Dalby (Assistant Engineer of the Bengal-Nagpur Railway Company) has shewn in a very lucid section what appears to be the relation of the borehole to the Eeb river seam. I have reproduced this section—Horizontal Section B.—as it represents also my own idea on this point; but I must add that I differ from Mr. Dalby on the question of the general correlation of the seams shewn with those in the neighbourhood of Durlipali—there appears to have been a general consensus of opinion that the Eeb bridge seam was the same as the seam exposed, near Durlipali, in the Lillari, 6 miles west-south-west. The conglomerate shewn in the section is at the top of the lowest of the zones into which I have divided the Barakars.

In my own exploration in this area I was successful in unearthing a coal-seam outcropping at two points on the left bank of the Eeb about $1\frac{3}{4}$ and 3 miles down the river from the bridge, R^7 and R^6 on map.

That the seam unearthed at the first point R^7 is the same as the Eeb river seam the associated strata would appear to place beyond doubt, the overlying conglomerate being well in evidence. As regards the more southern exposure R^6 (near Rampur) identification is not so easy. No rocks are visible for some little distance on either side, and such as are seen are pitching about at

high angles in all directions. Still a few conglomerates occur in the neighbourhood, and moreover the section of the seam, as deep as the pit sunk into it could be taken with the labour at hand, was to a favourable degree analogous with the more northern section, so that one is justified in assuming this to be also the Eeb bridge seam.

Reverting to Mr. Dalby's section—Hor. Section B—of the strata near the Eeb bridge, the coal-seam exposed at Lumchibahal bridge (R^5 on Map) is shown as analogous to the Eeb river seam. Now although before studying this section I had, judging from the associated rocks, arrived at the same opinion quite independently myself, it is perhaps only right to remark that the distance from the Eeb river seam to the Lumchibahal seam (R^5) is $1\frac{3}{4}$ miles and that good exposures are very few in number. It will be seen then that this correlation is open to doubt, but such unlooked for support is, I think, sufficient to allow of its being considered as above stated.

On such grounds then the Eeb river seam can be said to have been proved at four points. With the exception of the bridge itself, holes were put down this season at all of these points and the sections as deep as the pits could be carried with the labour at hand are :—

	R^6 near Rampur.	R^7 South of Bridge.	R^8 Lumchibahal.	Eeb Bridge.
Conglomerate . .	...	...	...	Beyond the statement that 16 feet of workable coal was met with, of which 8 feet were of excellent quality, no detailed section is to hand.
Grey shale . . .	...	...	7′ 0″	
Black earth . . .	4′ 0″	6′ 0″	5′ 6″	
Coal	4′ 9″	2′ 2″	1′ 6″	
Bat	8″	1′ 6″		
Coal	3′ 1″	3′ 3″		
Bat	1′ 9″			
Coal anticipated . .				

When the first borehole failed to strike this Eeb river seam the idea of a fault downthrowing to the east appears to have been worked upon, and a borehole was started at Luchkura a little over 2 miles to the westward. Now the surrounding rocks are dipping at an average of 1 in 12 to westward, so that one would expect to find the outcropping rocks at the Eeb bridge about 900 feet deep at Luchkura, or assuming 900 feet of an upthrow to westward, surface rocks at the Eeb bridge to be at the surface at Luchkura. But although the idea of the throw of the fault is a very rough one we know that it can be but very little above 200 feet, if that much, and therefore a seam on the surface at the Eeb bridge should be expected to be about 700 feet deep at Luchkura. The borehole was 41 feet deep, and from the section it will be seen that four feet of coal was struck at a depth of 29 feet and that afterwards eight feet of shale was passed through. Strange as it may appear this coal-seam was at once said to be the same as the Eeb river and Durlipali seams. The difference in thickness was accounted for on the supposition that the seam had not been struck at the top but somewhere in the middle.

No. 2 borehole, Luchkura.

To further test the seam at this point a small shaft (53 feet deep) was put down a little to the west of the borehole and it was expected to have to go to a depth of at least 50 feet before touching the seam. At 36 feet, however, coal was struck and a 17 feet seam passed through, the shaft being stopped in sandstone. The Assistant Engineer (B.-N.Ry.), who was in charge of the shaft at the time, gave it as his opinion that the seam bored through in the borehole had not been struck in the shaft. I do not know the distance of the borehole from the shaft, but it seems to me that since four feet of coal was anticipated at 50 feet deep and the shaft was passing through coal at that depth and left it at 53 feet, some reason should have been given for the opinion. One point, however, is certain, that if the seam in the borehole and shaft are not the same, the lower one, borehole seam, must be directly below the upper one since the bottom of the 17 feet seam is 3 feet lower than the level at which the top of the borehole seam was estimated to occur. I was fortunate enough to see some of this seam which had

Luchkura Shaft.

been extracted lying by the side of the shaft. The heap had certainly been weathering for eight or nine years, but nevertheless it bore so great a resemblance to the Durlipali shale bed that I have assumed it to be the same; no data at present known except perhaps the difference of thicknesses of the seams—which, at such distant points as Durlipali and Luchkura, ought not to be allowed much weight—militate against this assumption, but opinions formed afterwards tended to confirm its correctness.

Reverting again to horizontal section B of strata near the Eeb river, borehole No. 2 (Luchkura) is seen so placed as to show that the seam it struck was the same as that exposed near Lumchibahal bridge, which I have correlated with my Eeb river seam. Considering now that the distance from Lumchibahal bridge to the shaft at Luchkura is a mile and a quarter and that the rocks exposed between these places are dipping at 5° to the westward, such correlation requires corroboration. Until such is forthcoming all that can safely be assumed must be based upon the dips of the rocks. Considering such then we can only say that at the Luchkura shaft a seam of coal seventeen feet thick has been proved, and that, from the dip of the strata, this seam appears to be overlying the coal-seam exposed at Lumchibahal bridge, from which it is apparently separated by a thickness of from 400 to 500 feet of measures.

If then the Lumchibahal bridge seam is, as I believe with Dr. King and Mr. Dalby, the same as the Eeb river seam and the Luchkura seam is identical with the Durlipali seam, it follows that the Eeb bridge seam appears to be some 400 to 500 feet or more below the Durlipali seam and this I am inclined to believe is the case. The

Borehole No. 3.

next borehole, *i.e.*, No. 3, which might have given some evidence confirming this, cannot, however, be considered, its exact position not being known.

The Kodopali (No. 4) borehole does not afford any direct evidence on which correlation of seams can be made. At a depth of 15 feet a 40 feet seam of coal was struck. To prove this seam of coal on a larger scale

Kodapali, No. 4 Borehole.

an experimental shaft was sunk on to it and several tons of coal extracted. I have not seen any report on the tests made with the coal extracted, but from the appearance of the coal stacked near the shaft, I would have judged the seam as worthless: subsequent experiments confirmed this. The original depth of the borehole was only 60 feet, it having been thought unlikely that there was more coal at a greater depth. As explained previously, Mr. Griesbach, Director of the Geological Survey, was not satisfied that there was no more coal at a greater depth, and Government acting on his advice sanctioned the deepening of the Kodopali borehole until the Talchir rocks were struck. This borehole was stopped at a depth of 485 feet, before reaching the Talchirs.

The coal proved by the borehole, at a depth of 15 feet, and in the shaft, was described as evidently the same as the Durlipali and Eeb river seams. The Kodopali Diamond Drill boring appears to have been put down on this assumption and is therefore supposed to have proved nearly 500 feet of measures below the Durlipali seam.

Kodopali No. 4, Diamond Drill boring.

Now beyond a similarity in the appearance of the seams and a very rough alignment of the Kodopali boring with the strike of the Durlipali seam, there are no grounds that I know of for correlating the Durlipali and Kodopali exposures, and when it is remembered that the distance from the Durlipali outcrop to the Kodopali boring is three miles, such an assumption can be, to say the least, only of little worth. There can be no doubt that the ground proved by the Diamond boring is near the base of what I have made my third zone, but at present there are no data sufficiently well substantiated to fix the exact horizon of the top of the hole. My own opinion is that it is some 200 feet or more above the top of the Durlipali seam. Be that as it may, the borehole verifies the Director's opinion that coal does exist below the seam proved in the shaft, and generally gives results sufficiently encouraging to justify further exploration of the lower Barakars.

Workable seams struck in the Kodopali boring.

On reading the record of the Kodopali boring, I selected six bands of coal worthy of consideration, namely:—

No. 1—at a depth of 42 feet and described in the boring record as—8 feet of shaly coal with 2 inch and 4 inch shale partings.

No. 2—at a depth of 340 feet 6 inches and described in the record as composed of—

	′	″	
Coal (shaly)	1	0	9′ 6″ of coal, and 1′ 0″ of shale.
Coal	2	0	
Carbonaceous shale	1	0	
Coal (shaly)	2	0	
Coal	2	6	
Coal (shaly)	1	0	

No. 3—at a depth of 352 feet 8 inches and composed of—

	′	″	
Coal	2	0	9′ 7″ of coal, 1′ 0″ of shale.
Carbonaceous shale	0	6	
Shaly band	0	6	
Coal	4	6	
Coal (stony)	0	6	
Coal	2	7	

No. 4—at a depth of 361½ feet and described in the record as composed of—

	′	″	
Strong coal	0	6	5′ 4″ of coal.
Coal	4	10	

No. 5—at a depth of 375 feet 9 inches and described as composed of—

	′	″	
Coal	2	6	9′ 3″ coal, 1′ 0″ shale.
Coal (stony)	0	6	
Coal	1	0	
Carbonaceous shale	0	3	
Coal	2	9	
Carbonaceous shale	0	9	
Coal	2	6	

No. 6—at a depth of 388 feet 7 inches and described as composed of—

	′	″	
Coal	2	6	8′ 10″ coal.
Coal (stony)	2	0	
Coal	0	3	
Coal (stony)	0	9	
Coal (fair 1 foot)	2	0	
Coal	1	4	

Had these sections been correct, each one of the above seams would have been thick enough to be worked at a profit supposing the coal to be of the average Indian quality. On comparing the record with the boring cores, however, I found that, with the exception of No. 3, each one of these seams had been badly recorded; carbonaceous and even argillaceous shales had been raised to the dignity of coal to such an extent that the idea of working these seams (except No. 3) could not be entertained. The section of No. 3 would be more correct if stated:—

	Carbonaceous shales	3	0
Coal		4	7
	Stony shale	0	5
Coal		2	0
	Stony shale	0	7
Coal		0	6

} 7′ 1″ of coal.

Dhoramuda, No. 6 Borehole.

It has been remarked that the object of the Kodopali borehole was to prove the lower Barakar measures. At present as stated the lower Barakars have not been touched. It was evidently with this object still in view that the Director of the Geological Survey advised the deepening of the Kodopali borehole. Could this have been carried out at the time, a definite opinion as to the value of the field would in all probability by now have been arrived at. Unfortunately the boring contractors were not equipped with deep-boring tackle, and when later the work of proving the lower Barakars was undertaken, it was considered a better plan to bore through the whole thickness of the Barakar rocks. Owing undoubtedly in a very great measure to the inaccurate topographical map the thickness of the Barakars appears to have been under-estimated and as a consequence the site of the borehole—Dhoramuda—was chosen too high, geologically speaking, for the object of the borehole to be accomplished with the tackle at hand.

It must not be understood, however, that this boring has served no useful purpose, for it certainly has proved that at this spot and consequently at all others on the same geological horizon, the depth at which good coal lies in the lower Barakar measures (supposing it

to exist there at all) is such as to render it unworkable in the present state of Indian mining.

In a direct line from the Dhoramuda (No. 6) to the Kodopali (No. 4) borehole is a distance of fully six miles. The country is very jungly so that good surface exposures are practically absent. Under these conditions it is obvious that any figures intended, at present, to fix the relative horizons of the Kodopali and Dhoramuda borehole must be viewed with a very elastic mind. I have stated earlier in this paper that there appears to be still a thickness of some 500 to 600 feet of measures between the bottom of the Dhoramuda and the top of the Kodopali boreholes, but for the reason given above this can be but a very rough approximation.

Owing to their different geological horizons no correlation of seams in the (Dhoramuda) borehole can of course be established with those of the Kodopali borehole. Nos. 5 and 6 boreholes of Dr. King (Rec. Geol. Surv. Ind., Vol. XIX) appear to have passed through the same rocks as the Dhoramuda borehole.

Analogy of seams at Dhoramuda to those proved by Dr. King (Rec. Geol. Surv. Ind., Vol. XIX).

The seams met with at depths 184 feet and 62 feet in No. 6 borehole (Dr. King) may be taken as the representatives of the seams proved by the Dhoramuda borehole at depths of 772 feet and 685 feet 9 inches; and those at 203 feet, 114 feet, and 37 feet in Dr. King's No. 5 borehole as representatives of seams proved at Dhoramuda at 471 feet, 338 feet, and 309 feet.

The data for such supposition are as follows:—

Coal seams proved in the Dhoramuda (1899) Borehole.

Dr. King's No. 5 borehole lies (as nearly as I can gather from the Records) ⅛ mile to the rise of the line of strike of the beds at the Dhoramuda borehole. The dip is not very constant over the intervening country, but 1 in 12 is perhaps a fair average. From this it can be found that a seam near the surface at the No. 5 borehole of Dr. King (near Khaliabahal) will be about 276 feet deep at Dhoramuda. This gives the correlation for Dr. King's No. 5 borehole, and since the main sandstone bands fall in more or less

with this, little doubt can remain as to its probable correctness. Reasoning similarly with Dr. King's No. 6 borehole the carboniferous bands proved can be correlated as illustrated. This correlation is of great use in indicating which of the seams proved by the Dhoramuda borehole are exposed in the Lillari nala. For instance, Dr. King (Rec. Geol. Surv. Ind., Vol. XIX, page 212), shews that the first coal struck in his No. 5 borehole was the same as that exposed near Khaliabahal and the first in his No. 6 borehole that exposed near Bonjari. From the boring record of the Dhoramuda hole one is able to mark out eight seams of coal as appearing to be of workable thickness :—

			Ft.	deep.
1°	described as	24 ft. of carbonaceous shale and coal at	255	„
2°	„	„ 16 ft. of coal (shaly) at	309½	„
3°	„	„ 10 ft. of coal (shaly) at	471	„
4°	„	„ 3 ft. 6 ins. coal (shaly) at	504	„
5°	„	„ 15 ft. 6 ins. coal (shaly) at	644	„
6°	„	„ 9 ft. 0 ins. coal (shaly) at	672	„
7°	„	„ 5 ft. 9 ins. coal (shaly) at	685½	„
8°	„	„ 4 ft. 0 ins. coal (shaly) at	768	„

No. 1 in Dhoramuda borehole, the Khaliabahal exposure.

On looking at the boring core it can at once be seen that Nos. 1, 3, 4, 5, 6 and 7 can be dismissed from further consideration as of no practical use whatever, being simply cases of bat, *i.e.*, bituminous shales—sometimes grit sandstones included,—raised to the dignity of coal. It is of interest to note, however, that No. 1 is identical with the Khaliabahal exposure. Now during my work in the field this season I sank a little shaft in this exposure and satisfied myself that it did not contain coal of sufficient thickness or quality good enough to be workable.

The section obtained was :—

	Ft.	In.
Top clay	2	0
Shale	0	4
Coal	0	4
Shale	0	4
Shale with coal pipes	2	4
Shale	1	0
Coal	0	6
Shale	0	5
Coal	0	2
Shale	0	2
Sandstone base		

There is as will be seen 1 foot of coal in the whole section. To form an idea of the nature of such coals, I extracted some of this foot of coal and tested it getting upwards of 35 per cent of ash. Dr. King's general analysis of the whole seam gave :—

	%
Moisture	8·20
Volatile matter	22·21
Fixed carbon	25·16
Ash	44·43
	100·00

No. 7 in Dhoramuda borehole, the Bonjari exposure.

Perhaps also it will be as well to record that the No. 7 seam is the one exposed near Bonjari and therefore the same as Dr. King's 7 foot seam at 62 feet deep in his No. 6 borehole. I also sank a small shaft into this exposure and obtained the following section :—

	Ft.	In.
Carbonaceous shale	2	0
Ironstone	0	3
Carbonaceous shale	2	3
Coal	0	9
Carbonaceous shale	1	0
Coal	0	5
Carbonaceous shale	0	9
Coal	0	5
Carbonaceous shale	1	4
Coal	0	2
Carbonaceous shale	0	7
Sandstone base		

Here again then is an insignificant thickness of coal. A test on the coal alone gave upwards of 35 per cent. of ash. An average analysis throughout the seam is given by Dr. King :—

	%
Moisture	6·44
Volatile matter	25·03
Fixed carbon	29·22
Ash	39·31
	100·00

These two seams just discussed (Nos. 1 and 7) may be taken as typical of the other four (Nos. 3, 4, 5, and 6), and all can therefore be dismissed from further consideration.

This leaves us then with only two (Nos. 2 and 8) coal-seams of workable thickness in the Dhoramuda borehole. No. 2 described in the Record as 16 feet of shaly coal appears from the core to be—

	Ft.	In.	
Coal	3	7	7′ 3½″ coal, 1′ 0½″ shale.
Shaly band	0	8	
Coal	1	11½	
Shaly band	0	4½	
Coal	1	9	

No. 8 is as described 4 feet of coal.

CHAPTER IV.

WORKABLE THICKNESSES OF COAL PROVED.

So far then only four seams of coal out of the many struck have upon examination proved to be of workable thickness. Beginning at the top and in descending order these are:—

1° The seam proved in the Dhoramuda borehole at a depth of 309¾ feet, the section of which is given just above and is shewn to be composed of 7 feet 3½ inches coal with one foot of shale interbedded.

2° The seam proved in the Dhoramuda borehole at a depth of 768 feet, containing four feet of coal.

3° The seam proved in the Kodopali borehole at a depth of 352⅔ feet, composed of 7 feet 1 inch of coal with one foot of shale interbedded.

4° The Eeb bridge seam of which the best section obtained shows 7 feet 10 inches of coal with 8 inches of bat (hard bituminous shale) interbedded.

Quality of the coal.

I have made careful analyses of these four seams and tested their calorific powers.

It must be remembered, however, that the samples of Nos. 1, 2, and 3 seams, of which the analyses were made, were taken from the cores of the diamond drill boreholes put down in February 1899

(Dhoramuda) and 1896 (Kodopali). The cores had of course weathered, but I am inclined to think that the analysis may be taken as fairly representative of the seams, in the neighbourhood of the boreholes.

The tests on the Eeb bridge seam were made on fresh general samples extracted by myself from little shafts put down this year near the outcrops.

The following are the results of the analyses:—

NO. 1.—DHORAMUDA AT A DEPTH OF 309¾ FEET.

	Top 3′ 7″.	Middle 1′ 11½″.	Bottom 1′ 9″.
	%	%	%
Moisture	7·3	7·9	9·8
Volatile matter	21·9	25·4	21·1
Ash (white)	40·0	35·1	30·7
Fixed carbon	30·8	31·6	38·4
	100·0	100·0	100·0

NO. 2.—DHORAMUDA AT A DEPTH OF 768 FEET.

Moisture	6·2
Volatile matter	19·0
Ash (yellowish white)	31·4
Fixed carbon	43·4
	100·0

NO. 3.—KODOPALI AT A DEPTH OF 352⅔ FEET.

	Top 4′ 7″.	Bottom 2′ 6″.
	%	%
Moisture	4·6	7·5
Volatile matter	17·5	19·6
Ash (reddish)	35·3	34·4
Fixed carbon	42·6	38·5
	100·0	100·0

No. 4.—The Eeb Bridge Seam.

	R^7 (south of Bridge).	R^6 (near Rampur).
	%	%
Moisture	8·0	9·0
Volatile matter	20·9	24·3
Ash (buff)	18·9	11·8
Fixed carbon	52·2	54·9
	100·0	100·0

Considering the above results it will be seen that Nos. 1, 2, and 3 are not of good enough quality to be of themselves workable and it is a question whether No. 1 can at present be profitably used for any purpose. As time goes on, however, it is not unlikely that a seam even of this quality may be in demand, but for the present I do not think such a seam can be considered as a factor in the value of the field. No. 2 is a little better, but is a thinner seam. It is not, however, unlikely that in the near future this seam together with No. 3, which is of about the same quality, but a little better section, may be worked for local consumption, mills, etc. For high temperature, *e.g.*, smelting, etc., the seam is of but small value.

No. 1.

Nos. 2 and 3.

No. 4 [1] is the seam "par excellence" of this coal-field. The coal is of good steam quality and is eminently suited for locomotives or stationary boilers. It is free burning, does not clinker and leaves a buff coloured ash. Its average calorific power is 12·7. It is non-caking and compares very favorably with Raniganj coals.

The Eeb river seam then if it can be proved to cover sufficient workable area and maintain section and quality similar to that proved at the two exposures,

Eeb River Seam. *Practical considerations.*

[1] The analyses of the samples from the two outcrops of this seam, *i.e.*, R^7 and R^6, will be seen to differ considerably in amount of ash. In the earlier part of this paper I have reasoned that these outcrops are outcrops of the same seam. The possibility of their being two seams must not, however, be overlooked; in fact the difference in percentage of ash is an argument in favour of this, but perhaps not a very strong one since the two exposures are a mile and a quarter apart.

R^7 and R^8, can be considered, *per se*, profitably workable. There is every reason to suppose that the seam extends over the greater portion of the Barakar area being low down in the Barakar horizon. On the sketch-plan I have marked what from present geological data would appear to be the outcrop of this seam, but, as has been previously remarked, data are very few and surface evidence wanting, so that the mapping of the outcrop can only be looked on as an approximation.

The question arises as to how to prove the extension and capabilities of this seam. The best way, of course, is to prove the outcrop of the seam for some distance. Starting say from R^6 exposure near Rampur a series of hand boreholes might be put down along a line going westward towards Durlipali. Such boreholes, however, must be put down in a systematic manner and the exact relationship of the section of any one to that of the previous one and the Eeb river seam be ascertained before another borehole is put down further to the west. The same method might also be applied along the line of the outcrop marked as running northwards from Rampur, but sufficient ground would, in all probability, be proved in the first case to warrant mining operations and plant. As far as the outcrop on the right bank of the Eeb river is concerned, it should not be lost sight of even if, as supposed is the case, it represent a patch cut off by a fault from the main area. There is ample room for a small plant; it is not unlikely, however, that water will be a trouble.

General consideration.

I have stated previously that the bottom of the Dhoramuda borehole appears to be from 500 to 600 feet above the top of the Kodopali borehole and that the bottom of the Kodopali borehole has not struck the Talchirs.

Sketch section A illustrates what I think is approximately the relation of these boreholes to one another. I have scored in red the lengths unproved by the Dhoramuda and Kodopali boreholes which may amount to from 600 to 800 feet or more.

The thickness of measures above the Kodopali borehole—reference B in Horizontal Section A.—appears to have been proved by Dr. King (Vol. XX, Rec. Geol. Surv. Ind., boreholes Nos. 7 and 8), but

since no record is kept of the exact positions of the boreholes put down in this exploration and no relationship definitely established between them, it is not possible to draw up a complete vertical section nor even to be certain that the ground is thoroughly proved. However by surface observations I satisfied myself that no workable coal-seams were present in this zone, and I am therefore able to dismiss it from further consideration.

As regards the lower unproved length—reference D, Section A—it is in this zone that the Eeb river seam occurs. I gave special attention to the area occupied by the rocks of this length, but was unable to get data from which to compile a complete section. In my preliminary report on this area I advised that a borehole should be put down to prove this length or the Kodopali borehole completed to the Talchir Rocks. A good place for such a borehole would be ⅛ mile east-south-east of Kodopali. A borehole so placed should pass through the Eeb seam and be of great help in fixing its exact horizon and facilitating the determination of its outcrop.

Conclusion.

From a commercial point of view then I would advise further enterprise, a good seam of steam coal and also two seams of coal of rather inferior quality, but of workable section (which might be used for mills and local consumption) having been proved to exist within easy reach of the railway. It is necessary, however, before putting down plant to work the main seam, to prove its extension. It has been recommended that, while this work is being undertaken, the lowest 200 feet of the Barakar measure should be proved by a Diamond boring put down on to the Talchirs about ⅛ mile east-south-east of Kodopali. It is not possible to state with any idea of certainty what the actual depth of such a borehole will be, but I do not think it will exceed 600 feet—it will probably be much less.

Appendix.

BORING RECORDS, RAMPUR COAL-FIELD.

The Dhoramuda Borehole, Lillari Valley.

Strata passed through.	*Thickness in feet.*	
Alluvial clay (sandy)	14	
Soft loose brown grey sandstone (coarse)	5	
Brown and white sandstone	6	
Carbonaceous shale	5	
Sandstone	2	
Grey sandy shale	2	
Dark shale	3	
Grey sandy shale	3	
Dark slaty shale	3	
Grey sandy shale	7	
Coal	1	
Shale (sandy)	6	
Sandstone	5	
Coal	0'25	
Shale, grey	7'5	
Coal	1'75	
Sandstone	3	
Sandy shale	4	
Carbonaceous shale	0'5	
Sandy shale	3	
Shale clay	4	
Sandy shale	6'5	
Grey sandstone	6'5	
Grey shale	1	
Grey sandy shale	6	
Shaly sandstone	7	
Coal (shaly)	1	
Shaly sandstone and grey shale	19'75	
Coal (shaly)	1'25	
Grey sandstone	18	
Coal (shaly)	1	
Grey sandstone shales	26	
Coal (shaly)	2	
Possiliferous shales	14	
Carbonaceous shales carrying thin bands of shaly coal	10	
Sandy blue shale	5	
Shale carrying coal	2'25	
Grey shaly sandstone	41'75	
Carbonaceous shale and *coal* (shaly)	24	(1)
Blue and grey sandstone (shaly)	30'75	
Coal (shaly)	16	(2)
Argillaceous shales	12'25	
Carbonaceous shales with *3" to 6" bands of coal and shaly coal*	21'5	
Grey sandstone	54'5	
Grey and blue shaly shales	50'75	

	Thickness in feet.	
Black trap and carbonaceous shale	6·25	
Coal (shaly)	10	(3)
Grey and blue shales	23	
Coal (shaly)	3·5	(4)
Blue and grey sandy shales	8·5	
Coal (shaly)	1	
Blue and grey sandy shales	24	
Coal (shaly)	1	
Grey sandstone carrying *strings of coal*	28·	
Coal (shaly)	1·5	
Grey sandstone	12·5	
Coal (good)	1·25	
Grey and blue shale and sandstone	58·75	
Coal (shaly)	15·5	(5)
Sandy grey shales with 3" *seams of coal*	8·5	
Coal (shaly)	2	
Carbonaceous shales with *coal*	2	
Coal (shaly)	9	(6)
Grey shaly sandstone	4·75	
Coal (shaly)	5·75	(7)
Shale and sandstone	5·5	
Coal (shaly)	·5	
Dark blue shale and grey sandstone	70·5	
Coal (shaly) in parts fair	4	(8)
Carbonaceous shales and coal shales	15	
Grey and brown sandstone	21·5	
Dark blue carbonaceous shales	7	
Dark grey shale	8	
Carbonaceous shale with coal	2	
Blue shale	2	
TOTAL—	828½ feet.	

THE KODOPALI BOREHOLE.

Alluvial soil	2·5	
Laterite	3	
Ironstone band	4	
Chalk	6	
Bituminous shales	18·5	
Shaly coal with 2" and 4' shale partings	8	(1)
Shale	3	
Argillaceous shale	10	
Fine dark grey shaly sandstone	15	
Argillaceous shale	1	
Fine dark grey shaly sandstone	10	
Blue argillaceous shale	7	
Coarse grey sandstone with fossiliferous dark partings	2	
Slaty shale	5	
Coal (shaly)	2	

	Thickness in feet.
Argillaceous shales	6
Fine bluish grey shaly sandstone	14·75
Hard grey sandstone	1·25
Coal (shaly)	2·5
Argillaceous shales, light and dark	19·5
Fine grey and blue sandstone	7
Shale	1
Grey sandstone (shaly)	4
Argillaceous blue shales	10
Shaly coal	1
Hard brown clay	0·5
Shales	1·5
Grey sandstone, micaceous and soft at top part	
Grey sandstone, coarse and fine with shale partings	27
Grey shaly micaceous fine blue sandstone	
Coarse grey sandstone with shale partings (conglomerate)	1·25
Grey shale	0·5
Coal	0·25
Grey shaly blue sandstone	5
Blue shale	5
Grey shaly sandstone	14
Slaty dark shales	3·5
Argillaceous shaly sandstone	2·5
Blue shales, argillaceous	7
Grey sandstone shaly and micaceous	15
Conglomerate	1
Shale with pyrites	1·2
Shale	0·3
Grey sandstone (coarse)	1·5
Shale	1
Very coarse grey sandstone with pyrites	21·5
Shale	3·5
Clay shale with white specks	3
Carbonaceous shale	1·5
Shale (coaly)	1
Carboniferous shale	
Do. (coaly)	0·5
Carboniferous shale	3
Do. (coaly)	0·5
Carboniferous shale	1
Do. (coaly)	0·5
Carboniferous shale	1
Do. with light shale partings	9
Coal (shaly)	1·6
Shale	1·4
Coal	·6
Shale, light and carbonaceous	8·4
Coal	1
Carbonaceous shale	1

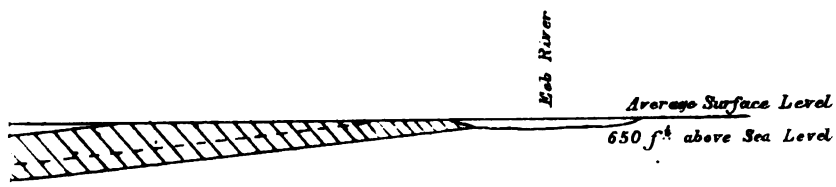
	Thickness in feet.
Carbonaceous shale	4
,, fine shaly sandstone	1
,, shale	3
,, ,, and *coal*	4
Coal	4
Carbonaceous shale	9
TOTAL	141 feet.

Water tapped at '5 ft.

No. 8 BOREHOLE.

Surface soil and clay	6
Vari-coloured sandstones and clays	19
Slightly carbonaceous brown shaly sandstone	2
Carbonaceous shale	4
,, ,, with a little *coal*	1
,, shale	8
,, grey shaly sandstone	15
,, shale	3
,, fine shaly sandstone	10
,, shale	3
,, ,, and *coal*	9
,, ,, and shaly sandstone	28
,, ,, and *coal*	3
,, ,,	10
Coal and carbonaceous shale	3
Carbonaceous shale	13
Coal	4
TOTAL	141 feet.

Water tapped at 20 ft.



BA

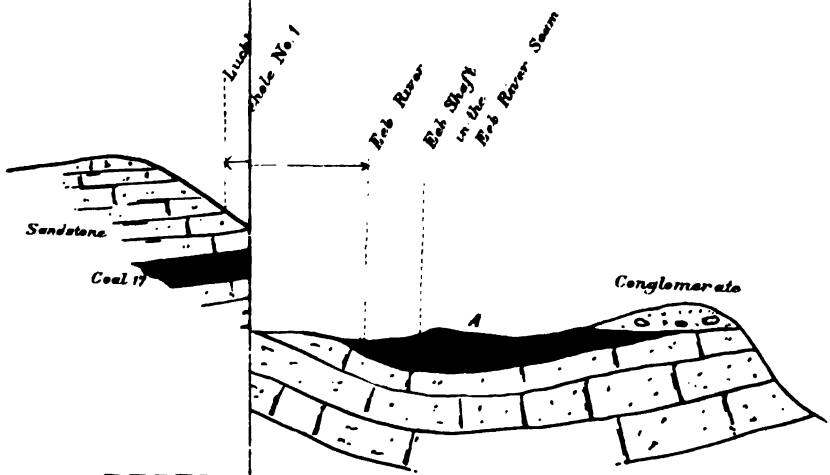
REFERENCE.

Series proved by Dhoramuda Borehole.
Series proved by previous boreholes & present survey.
Series proved by Kodopali Borehole.
Series not yet satisfactorily proved.

Scale: about 4 inches to 1 mile Hor. & Vert.

JDA.

W. E.



REFERE

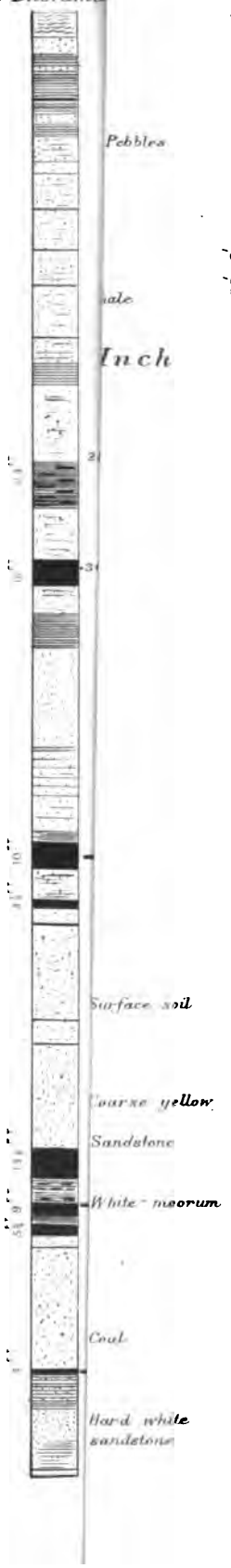
A Eeb River

B Supposed

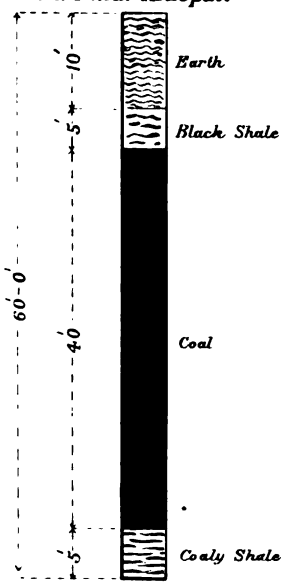
C Durlipali

SHOWAILWAY COMPANY.

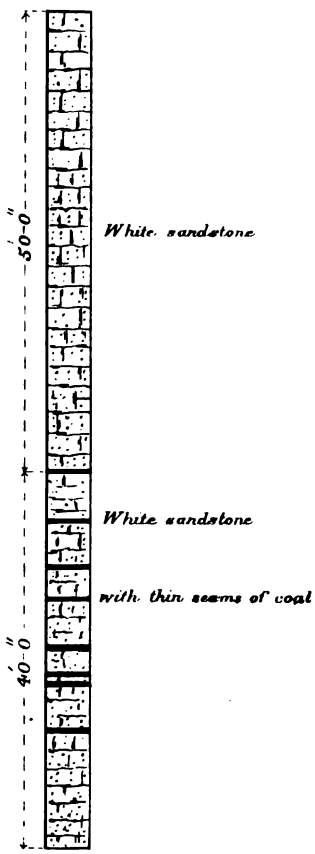
1899 Dhoramu



No. 4 near Kodopali



No. 5 near Job



Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 19th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *vid* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the microscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz-Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khâtan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanishtan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica-traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXXII, PART 4.

REPORT ON THE JAMMU COAL-FIELDS. *By* R. R. SIMPSON, B.Sc., *Mining Specialist, Geological Survey of India.*

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CONTENTS.

	Pages
I. Introduction— The principal coal consumers in North-Western India. Fuel equivalents. Importance of the exploitation of local coal-fields. Relation of the proposed Kashmir railway to the coal question	1—2
II. Position and physical features of the coal-field	3—4
III. Previous observers— Mr. H. B. Medlicott, Mr. T. D. La Touche, Mr. J. Godwin, Mr. A. Mort, Mr. Osterloh, Mr. E. L. Hope	4—5
IV. Origin of the present enquiry— Conference of Messrs. R. D. Oldham, E. L. Hope, and the Writer. Acknowledgment of assistance. Topographical map	5—6
V. Geology of the Ladda field— Age of formations. Folding. Generalised section. Details of the coal-bearing formation—Doodar ravine—Jungle ravine—Jungle gully to Sukhál gully—Anji valley—Between the Anji and Chenáb valleys—Between Mootal and Sandráni	6—22
VI. Geology of the Sangar Marg field— Geology. Details of the coal-bearing formation—Between the Chenáb River and Sangar Marg—The Ikni-Sujánpur slope—The Sujánpur synclinal—The Bugoola synclinal	22—28
VII. The Mehowgala, Siró valley, and Kálakót fields— The Mehowgala field—The Siró valley field—The Kálakót field	28—34
VIII. The Lodhra field— Physical and Geological features. Details of the coal-bearing formation—The Lodhra and Madiál nalas—The Thansu and Kolri nalas	34—37
IX. Nature and quality of the coal— Physical characters. Chemical composition and calorific value. Burning tests—Jammu water-works—Locomotives on North-Western Railway. Briquetting. Washing. Coking	37—56
X. Workable areas and quantity of fuel available— Results of the long drives in the Ladda field. Division of the coal-areas—The Ladda and Sangar Marg coal-fields—The Mehowgala field—The Siró valley field—The Kálakót field—The Lodhra field	56—64

XI. Economic aspects of the coal question—
Market value of Ladda coal. Most favourable position for a colliery. Probable output of coal. Estimates for the Ladda slope area—Estimate No. I—Bullock traction—Estimate No. II. Estimates for the Anji valley area—Estimate No. III—The proposed Anji valley branch of the Jammu-Kashmir Railway,—Estimate No. IV. Summary of Estimates . . . . . 64—70
XII. Suggested methods of working . . . . . 70—73
Appendix—
Note by Mr. E. L. Hope . . . . . 74—75

INDEX TO PLATES.

Plate 1. Map showing the Jammu coal-fields.
„ 2. Plan of prospects in Jungle ravine.
„ 3. Longitudinal section of Jungle ravine.
„ 4. Sections of the Ladda and Lodhra coal-fields.
„ 5. Jungle ravine.
„ 6. The Anji valley.
„ 7. The gorge of the Chenáb near Lodhra.
„ 8. The eastern portion of the Sangar Márg coal-field.
„ 9. Jungle ravine.
„ 10. Shaft-sinking, Siró valley coal-field.
„ 11. Faulting in the Siró valley coal-field.
„ 12. Graphic representation of the thickness of coal encountered in the long drives in the Ladda coal-field.

MEMOIRS

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THE GEOLOGICAL SURVEY OF INDIA.

REPORT ON THE JAMMU COAL-FIELDS. *By* R. R. SIMPSON, B.Sc., *Mining Specialist, Geological Survey of India.*

I.

INTRODUCTION.

The principal coal-consumers in North-West India.

The most important of the coal consumers of North-West India is the North-Western Railway Company. During the year 1901 this Company used, for locomotive and other purposes, a gross total of 179,174 tons of coal. Of this amount 31·4 per cent. was obtained from the Company's own collieries at Dandot (Punjáb), and Khost (Baluchistán), the former producing 24 per cent. and the latter 7·4 per cent. The major portion of their coal supply—68·6 per cent.—was, however, obtained from the coal-fields of Bengal. Over considerable sections of the Company's lines the use of wood fuel obtains. This source of supply is, however, year by year being curtailed, owing to the increasing cost of wood due to the depletion of the forests adjoining the railway line. As a consequence the use of coal tends to increase.

Fuel equivalents.

The following table shows the relative fuel equivalents of the various descriptions of locomotive fuel used on the North Western Railway. The figures arrived at were determined by the Company's own experiments in the year 1894:—

		Coefficient.	Equivalent.	
1 ton Giridih (Kurhurbaree) best steam coal.	=	1·25	0·80	English patent fuel.
„	=	1·10	0·90	English coal.
„	=	0·90	1·10	Bengal (Barákar) steam coal.

		Coefficient.	Equivalent.	
1 ton Giridih (Kurhurbaree) best steam coal.	=	0·78	1·28	Khost coal and patent fuel, including Shahrig coal.
„	=	0·64	1·56	Dandot, including Bháganwala coal.
„	=	0·45	2·20	Wood fuel.

Importance of the exploitation of local coal-fields.

The average cost of Bengal coal delivered at Ghaziabad, the nearest approach of the North-Western Railway Company's lines to Bengal, was, in 1902, Rs. 14-2-0. Of this sum Rs. 11-10-0, or 82 per cent., represents freight charges. From the above figures it can be understood of how much importance it is to the industrial development of North-Western India that the local coal-fields should be exploited, and new sources of cheap fuel obtained. It is, therefore, not surprising that from time to time various attempts have been made to open up the well-known coald-eposits of tertiary age in the north-west. Unfortunately, owing to the poor quality of the coal, and its irregular occurrence, only two (at Dandot and Khost) of these adventures have proved to be commercially successful. For some years past the attention of the Jammu and Kashmir Durbar has been directed to the possibility of mining coal profitably from the long-known coal-bearing beds in the Jammu hills.

The proposed Kashmir Railway and its relation to the coal question.

The question has recently been forced into prominence by a revival of the old project for the building of a railway to connect the cities of Jammu and Srinagar; the idea being that the alignment of the projected railway might be arranged to tap the coal-bearing area, and open up a cheap source of fuel for use on the railway. The interdependence of the railway and the coal schemes has, however, been somewhat discounted by Mr. Weightman in his report on the Kashmir Railway, where he has shown that the use of Jammu coal at an estimated cost of only Rs. 9 per ton, as against Bengal coal at Rs. 22 per ton, would effect a saving representing rather less than one-half of one per cent. interest on the capital estimated to be required for the railway. It, therefore, appears that the question of working the coal must be considered practically on its own merits.

II.

POSITION OF THE COAL-FIELDS.

Position.

The coal areas to be described—known as the Ladda, Sangar Marg, Mehowgala, Siró valley, Kálakót, and Lodhra coal-fields—lie between latitudes 33° and 33° 13′, and longitudes 74° 25′ and 75° 13′. They are situated in the State of Jammu, a portion of the territory of His Highness the Maharajah of Jammu and Kashmir, and within 35 miles of the boundary between that State and the Punjab.

The general trend of the coal outcrops is from north-west to south-east and the south-eastern end of the Ladda coal-field lies some 21 miles north-north-east of Jammu, the capital city of the State, and the nearest approach of the North-Western Railway. The Sangar Marg field is geologically co-extensive with the Ladda field, but the areas are separated by the Chenáb River and have been dealt with separately in this report. The Mehowgala, Siró valley, and Kálakot fields are detached areas lying from 5 to 13 miles to the west of Sangar Marg. The Lodhra field is situated about 10 miles north-east of the Ladda area.

Physical features.

The general character of the country is mountainous (see Plates V to IX), varying from three to nine thousand feet in height above sea-level. The strike of the coal-bearing rocks does not conform to any of the main natural features of the country, but cuts obliquely across the hill ranges, which have a general east and west trend. At the same time, owing to the relatively soft character of the coal-bearing band compared with the sub- and super-jacent rocks, the coal outcrops are, as a rule, found in or near the stream beds.

The country is fairly well wooded, the most abundant tree being a conifer, locally known as *chir*, from which excellent timber for mining purposes can be obtained. Of other conifers, *cuchil* and *deodar* are found on the higher ground; whilst of the harder woods, oak, walnut and occasionally holly occur.

The only made road in the Jammu State runs between Jammu and Udhampur, a distance of about 44 miles, and this road passes within seven miles of the prospecting drives in Jungle gully.

III.
PREVIOUS OBSERVERS.

The area has been described generally by Mr. H. B. Medlicott in his "Note upon the Sub-Himalayan series in the Jammu hills" (*Records, G. S. I.*, vol. IX, pt. 2). The Sangar Marg, Mehowgala, and Siró valley coal-fields have been described in detail by Mr. T. D. La Touche (*Records, G. S. I.*, vol. XXI, pt. 2).

The possible economic value of the Ladda coal-field first attracted attention in October 1901, when Mr. J. Godwin, an officer in the Public Works Department of the Jammu and Kashmir States, commenced prospecting operations in the Ladda coal-field, which have been carried on under his supervision up to the present time.

In January 1902, Mr. A. Mort, Manager of Khost Colliery, Baluchistán, visited and reported on the Jungle gully portion of the coal-field. His opinion was unfavourable.

In February of the same year, Mr. Osterloh, one of the Boer prisoners, took over the direction of the prospecting operations, and, during his stay of some seven months, considerably extended the area of the explorations. Although he has left no regular report, I gather from various sources of information that he was strongly impressed with the value of the Ladda coal-field.

Mr. Mort paid a second visit to the coal-field in June 1902, and a perusal of his report shows that his views were then considerably modified in favour of the existence and workability of the coal-seam over a considerable area.

In October of the same year, Mr. T. D. La Touche, Superintendent, Geological Survey of India, visited the locality and spent a few days in the Jungle gully area. In his report he expressed the opinion that the existence of a coal-seam with an average thickness of five feet had been proved over a horizontal distance of two miles, through

a vertical height of 1,700 feet. He drew attention to the possibility of the coal-bearing rocks being found at a reasonable depth and a more moderate inclination beneath the newer rocks to the south-west of the Jungle gully area, and he suggested that this might be tested by boring.

In December last, Mr. E. L. Hope, Manager of Dandot Colliery, spent three or four days in an examination of the coal outcrops and prospects between Jungle gully and the Anji valley, a distance of about nine miles. In an interesting and extremely practical report he expressed the opinion that a workable coal-seam extends over nearly the whole of this distance.

IV.

THE PRESENT ENQUIRY.

I arrived in Jammu on the 10th of March, 1903, and commenced an enquiry into the question of the economic value of the Ladda and Lodhra coal-fields—an enquiry which was completed early in the month of May.

Conference of Messrs. R. D. Oldham, E. L. Hope, and the Writer.

On the 28th of March, I was joined by Mr. E. L. Hope, Manager of the North-Western Railway Company's collieries at Dandot. On the 6th of April Mr. R. D. Oldham, Superintendent, Geological Survey of India, took over charge of the enquiry and remained on the ground until the 15th of that month. Mr. Hope left the coal-field a few days later. During the period of this association the coal question was thoroughly discussed, and I had the advantage of profiting by the intimate knowledge of Himalayan geology possessed by Mr. Oldham, and the practical experience of the working of thin and highly inclined coal-seams in India which Mr. Hope has acquired. Mr. Hope had previously reported on a portion of the Ladda coal-field, and his supplementary report re-affirming his earlier views is attached as an appendix to this communication. On November 5th, I returned to Jammu and examined the coal-fields west of the Chenáb. I also paid a brief visit to the Ladda coal-field, and finally completed the enquiry early in January 1904.

Acknowledgment of assistance.

I take this opportunity to express my obligation to His Highness Sir Amar Singh, K.C.S.I., Vice-President of the Jammu and Kashmir State Council, and to Mr. Colvin, I.C.S., the Resident in Kashmir, for kindly assistance to me during my tours. Messrs. Godwin and Stewart, who superintended the prospecting operations, worked extremely well, and I have pleasure in thanking them for their good work.

Topographical map.

The largest scale topographical map of the district available is the Atlas sheet, on a scale of 4 miles to 1 inch. Through the courtesy of the Kashmir Durbar authorities, I was enabled to secure an enlargement of this map on a scale of 2 miles to 1 inch, and the large map (Plate I) attached to this report is on that scale. It may be remarked of the original map (No. 29, Atlas sheet) that, whilst the position of the main ranges of hills, rivers, and streams appears to be accurate, the positions of many of the villages are not correctly marked. As far as these mistakes affect the position of the coal outcrops I have endeavoured to correct them, but such alterations cannot be considered to be more than approximately correct.

V.

GEOLOGY OF THE LADDA COAL-FIELD.

Age of formations.

The geology of the coal area is, in a general way, fairly simple. The rock groups represented are grey sandstones and red clays of Murree age, apparently of great thickness, lying conformably on a thin but remarkably well-defined band of "coal measures" (Subáthu beds) made up of soft shales, interbedded with thin bands of earthy limestone of varying thickness, containing towards the base a seam of coal. The limestone bands occasionally contain nummulites. The shales are frequently carbonaceous in the neighbourhood of the coal seam, and towards the base of the group become strongly ferruginous, the bottom bed being a thin but remarkably persistent pisolitic ironstone band.

This group is the representative in this area of the Subáthu beds.

It has been deposited more or less unconformably on an ancient land surface of unfossiliferous limestone which has been considered to be of lower Mesozoic age. The base of this limestone group—the *great limestone* of Mr Medlicott*—is nowhere seen It is apparently of great thickness, but, in the opinion of Mr. Oldham, reduplication along thrust planes has taken place Bands of shales, usually siliceous, and often flaggy, occur interbedded in the limestone. Veins of galena are found in it, and, in former times, were mined to some considerable extent.

Folding.

The whole of these rocks have been subjected to earth movements of considerable magnitude, acting apparently chiefly from the north-east. The result has been that the beds have been ridged up into a series of anticlinal folds having their principal axes in a north-west and south-east line. These general features of disturbance are accompanied by both normal and reversed faulting. Local contortion is abundantly displayed; whilst in the soft Subathu shales the squeezing out of beds is by no means uncommon. It is owing to the denudation of the crowns of the anticlines that the pre-tertiary limestone and Subáthu beds are displayed at the surface. On account of the high dip of the beds (30°—90°) the coal-bearing rocks occur as a narrow band from three to six hundred feet in width, fringing the underlying limestone, and separating it from the overlying sandstones and clays. The relative ease with which these rocks have been denuded sharply distinguishes them from the adjacent groups, the drainage channels almost invariably following their outcrop. For the same reason their examination is rendered difficult by the frequency of landslips from the harder rocks. Similarly, the bold and rugged outline of the limestone slopes is seen to be in sharp contrast to the smoother and more rounded features of the sandstones and clays.

Although the *coal measures* are undoubtedly continuous between the outcrops in the different coal-fields, yet they are separated at the surface by a broad band of younger rocks, and it will be convenient for the purposes of this report to describe the areas separately.

* Records, G. S. I., IX, 2.

The general section of the rocks, as seen between the village of Mootal and the Chenáb river, is as follows:—

Generalised section.

Formation.		Description.	Thickness in feet.
Tertiary.	Murree group.	Grey sandstones and red clays.	Unknown.
	Subáthu group.	Olive shales with thick bands of nummulitic limestone	50—100
		Olive shales with thin bands of nummulitic limestone	50—100
		Olive-brown shales	75—100
		Nummulitic limestone with thin bands of olive shales	25—50
		Olive shales, ferruginous	0—100
		Coal-seam, average thickness 2'7"	0—25
		Ironstone shales, often carbonaceous	7—32
		Ironstone	6—30
		Ironstone shales	10—30
		Ironstone, pisolitic at the base	6—50
Pre-tertiary.		Shales, yellow, olive, and dull crimson with ferruginous bands	0—300
		Siliceous grit	0—100
		Great limestone, dense, splintery, blue-grey in colour.	Unknown.

As described above, the principal geological feature of this area is that of a normal anticlinal flexure, broken and faulted on its steep southern scarp. From the accompanying map (Plate I) the outcrops can be seen to show a longitudinal waving, and to curve round the point of the anticline as its axis becomes depressed towards the south-east. To the south of the main anticlinal fault newer tertiary rocks cover the ground as far as Jammu City. They are much broken and faulted, and near the main fault itself inversion has taken place. For reasons which will be given later, it does not appear to be probable that workable coal will be found at a reasonable depth beneath the surface in this latter area. Section No. I, Plate IV, taken across the anticline between Sandráni and Santráni Kund (the line A. B. on the map, Plate I), will enable the geological features of the neighbourhood to be clearly understood.

Details of the Coal-bearing Formation.

Commencing from the south-eastern point of the anticline a recognisable coal seam is first seen at Lain (33°0′—75°5′) in the gorge of the Doodar river, about 400 yards above Doomwa, where the main stream is joined by the smaller Jungle stream. The position of the coal-seam, as recognized by Mr. La Touche in his recent report, is quite abnormal, since it is overlaid as well as underlaid by the *great limestone* (see Plate IV, section 2). The overlying limestone has apparently been forced up from below by a reversed fault running along the strike of the ironstone. The effect of this overthrust has been to cut out all but the lower members of the *coal measures*, and to crush and in places squeeze out even these. The ironstone and overlying shales can be seen in their true position at Doomwa, at the mouth of the gorge, but they are much contorted and broken up, and the coal-seam appears to be missing.

Doodar ravine.

At Lain, at a point about 40 feet above the bed of the river, a level has been driven along the coal horizon for a distance of 285 feet. The ground passed through consists of lenticular patches of coal lying between the ironstone and the overlying limestone. The coal is accompanied by a stiff, grey clay, evidently the crushed representative of the upper shales. Frequently the limestone forms the roof of the coal seam, and for the major portion of its length the drive has been blasted out of that rock. Thirty-two feet from the inner end of the level the coal thickens out gradually into a somewhat regular seam which in the face exceeds 5 feet in thickness, the roof not being found.

The section seen in the face is—

Stiff, grey clay	2′ 6″+?
Coal	5′+?

On the opposite side of the nala the Mootal level has been driven along the coal horizon in a south-westerly direction for a distance of 237 feet. This excavation had fallen in previous to my visit. It is said to have commenced in six inches of coal, which thickened to 10

feet at a distance of 51 feet, and decreased gradually to 2 feet at 101 feet. Beyond this point the limestone came down on to the ironstone, squeezing out the coal. The drive was continued in broken ground made up of boulders of limestone and sandstone (?) until 18 inches of coal was again encountered at 230 feet. This coal thickened to 25 inches at a distance of 237 feet, and the driving was then discontinued.

Passing up the slope from the Lain drive a thick coal outcrop is found on the crest at Lain, 250 feet vertically above the bed of the Doodar nala.

The section here is:—

Olive shales, broken	?	
Coal and coaly shale bands	20′	0″
Coal	15′	0″
Grey shales	10′	0″
Ironstone	?	

The dip at this point is 70° to S. 35° E. Some 70 feet further on, a trench, now fallen in, is said to have exposed, at a depth of 10 feet, from 10 to 15 feet of coal and shale, overlaid by 5 feet of shale, dipping 75° in a direction 50° east of south. Six hundred feet beyond, another trench, now collapsed, has proved the coal. The section is:—

Coal (at a depth of 20 feet), said to be	5′	0″
Shales	65′	0″
Ironstone	?	

It may be noticed that the shales have thickened considerably, and that the dip has decreased to 58° in a direction S. 63° E.

At the mouth of the gorge at Doomwa, (33°0′—75°5′), where, as mentioned above, the *coal measures* are found in their true position, a pit was sunk on the coal horizon to a depth of 20 feet, and revealed only a few strings of coal in a mass of clay and broken limestone.

Following up the Jungle stream the ironstone outcrop disappears under talus about 150 feet north-east of Doomwa, the stream bed being occupied by the olive shales and nummulitic limestone, which, with their overlying sandstones and clays, are much contorted and broken up. This disturbance continues for rather more than three-quarters of a mile. A short distance

Jungle ravine.

below trial trench No. I, the ironstone-outcrops, after passing over the high ground between the Doodar river at Lain and the Jungle nala, join the latter ravine and bend round to the north. At trial trench No. I, the ironstone can be seen to be slightly folded on the strike, this disturbance apparently representing the dying-out of the Doodar river fault. At this point a trench, now fallen in, is said to have exposed four feet of coal at a depth of 10 feet.

Continuing up the stream, the strike of the beds perseveres due north with small local bends, the dip being east at an angle of 45°. One thousand feet from trial trench No. I, a similar excavation, No. II, now collapsed, is said to have proved, at a depth of 8 feet, a thickness of 4 feet 6 inches of coal. The section at this point is:—

Olive shales and nummulitic limestone . .	235′ 0″
Coal	4′ 6″
Ironstone shales with bands 3″—10″ thick of ironstone, coaly in places	28′ 0″
Ironstone	5′ to 7′
Great Limestone.	—

Some 300 feet north the strike bends round to the north-west and continues on this line to the top of Gully pass (33°1′—75°5′). Some 400 feet beyond trial trench No. II, a long distance tunnel (Jungle A drive) was driven. At the time of my last visit this tunnel had advanced to a distance of 430 feet from its portal. After passing through a considerable thickness of detritus, coal was struck at 90 feet. Between 90 and 320 feet, coal and shaly coal, varying in thickness from 0 to 7 feet and averaging 1 foot 11 inches, was encountered. From 320 feet to 435 feet the coal, sometimes shaly in character, varied from 4 inches to 4 feet 3 inches, and averaged 2 feet 3 inches in thickness (see Plate XII, fig. I for graphical representation of thickness of coal-seam). A sample taken at a point 30 feet from the face, where the coal was 3 feet thick, gave only 11½ per cent. of ash.

About 2,100 feet beyond trial trench No. II, a flattened coal outcrop, 15 feet thick, is found. An inclined shaft (Jungle shaft) was put down here, but it had collapsed previous to my visit.

The following section is to be seen:—

Olive shales and nummulitic limestone . . .	?
Grey-blue, shaly clay with limestone nodules . .	6′
Coal (said to thin out to 6 feet at a depth of 40 feet) .	15′
Ironstone and ironstone shales, carbonaceous in places .	10′ to 15′
Great Limestone.	

The dip is to the north-east at an angle of 30°, but it is said to have increased to 45° in the shaft.

Three hundred and fifty feet beyond Jungle shaft the dip is 50° in a direction N. 50° E.; the section is as follows:—

Olive shales with bands of nummulitic limestone .	68′+
Coal	ill defined
Shales with ironstone	20′
Ironstone	12′
Ironstone shales with carbonaceous bands . . .	50′ (?)
Ironstone	thin.
Great Limestone.	

A level (Jungle drive) was driven in at this point. Owing to the position of the coal in the stream bed, the excavation was commenced in the upper shales and curved gently round until the coal seam was struck at 62 feet. The coal was 3 feet 6 inches thick and thickened to 13 feet at 100 feet, gradually thinning to 8 feet at 118 feet In the last 30 feet of this length the strike bends round sharply to the north. As it was considered that the original strike would continue further ahead, and it being desirable to preserve the original direction of the tunnel, the workmen were brought back to the point where the strike changes, and continued to drive on straight ahead, in soft ironstone and clay, in the expectation of cutting off the corner. Coal about one foot thick was struck in the floor at 150 feet. A small quantity of inflammable gas (probably light carburetted hydrogen) was given off here. This gas, collecting in a cavity in the roof, ignited and caused a slight explosion, which singed the mine superintendent whilst he was making his examination. Since that time (November, 1902) the driving of this level has been discontinued. At the time of my visit I made a careful examination with a safety lamp, but was unable to find a trace of gas.

About 100 feet beyond Jungle drive, a parallel tunnel for ventilating purposes has been driven in for a distance of 50 feet; and at that point encountered a strike fault. The throw of this fault has not been proved.

On my first examination of this locality, although I noticed that the rocks were much disturbed, I did not fully appreciate the actual geological conditions. On paying a second visit in company with Mr. Oldham, he pointed out that a considerable landslip has taken place at this point. This slip is fully 1,000 feet in length and has moved down on the face of the lower ironstone bed. Both Jungle drives and the shaft have been excavated in its crushed and broken fragments. For this reason the prosecution of these excavations has been discontinued.

Some 700 feet beyond Jungle drive the coal is again seen. Owing to the broken nature of the ground, it was not considered prudent to drive on the seam, and consequently a drive (No. A) was commenced in the lower shales, striking the coal at a distance of 105 feet from the commencement. The coal was found to be very loose and crumbling and its thickness was not ascertained. The excavation has since collapsed. The surface dip here is 40° in a direction N. 40° E. This dip is preserved as far as and beyond trench B (1,100 feet from drive A) where, in an excavation, 8 feet deep (now collapsed), the coal seam is said to have measured 3 feet 6 inches in thickness.

About 450 feet further on, in an excavation (drive C), also fallen in, the same thickness of coal is said to have been proved. Drive D is 1,300 feet beyond drive C, and was commenced in the upper shales. Coal, 2 feet thick, was struck at a distance of 26 feet. At 41 feet, ironstone came in. The drive was continued for 70 feet further without striking coal This excavation is now closed.

At a point 100 feet south-east of D drive, a pit (No. I) was sunk on to the ironstone, at a depth of 26 feet. Rounded sandstone boulders lying on the ironstone, and the absence of coal, show that the pit has been sunk in talus. Two hundred feet beyond drive D, No. II pit was sunk, to a depth of 25 feet, with a similar result.

The most important prospect of all that have been made is drive E,

situated 1,100 feet short of the crest of Gully pass. This tunnel was commenced in the upper shales, and struck coal at a distance of 70 feet. Between this point and the face of the drive, at 550 feet, the thickness of coal varied from 0 to 8½ feet and averaged 3 feet (see Plate XII, fig. 2 for graphical representation of thickness of coal seam). The assay of samples from this drive yielded ash varying from 22 to 42 per cent.

Two inclined shafts have been driven down in the coal seam, from the outcrop, and connected with E drive. In the first of them the coal was, at the outcrop, 6 feet thick, but between points 30 and 70 feet respectively from the start the seam thinned to 2 feet 6 inches in width, and then thickened to 8 feet. Between 70 and 85 feet (where drive E was holed into) the latter thickness continued. In the other shaft (Gully shaft), coal 6 feet thick was found for the first 40 feet of driving. Beyond this, and until the shaft joined E drive at a total distance from the outcrop of 97 feet, carbonaceous shales were encountered. The shaft was continued, on the full dip of the seam, for 45 feet below E drive. Throughout this distance an average thickness of coal of 6 feet was maintained. From time to time during the driving of the E tunnel and its shafts, small quantities of inflammable gas have been met with, and it was found necessary to introduce safety lamps into the workings.

At a point 37 feet beyond Gully shaft, a tunnel (drive F) was commenced in a coal outcrop 20 feet thick. This thickness became rapidly reduced, until at a distance of 35 feet the coal ran out. The barren ground continued to a distance of 146 feet. Between the latter point and the face of the tunnel at 302 feet the coal varied in thickness from 0 to 3½ feet and averaged only 9 inches (see Plate XII, fig. 3 for graphical representation of thickness of coal seam).

From drive F the coal outcrop can be traced for some distance up the nala, and it increases in thickness to 20 feet at a distance of 150 feet from the drive. Just before Gully pass is reached the ironstone bed can be seen to be much broken up by a series of small parallel faults, which cut diagonally across the strike and dip. This disturbance continues in a modified form right over the crest of the pass.

Between Jungle Gully and Sukhál Gully.

At a point 100 feet beyond Gully pass, a drive (Gully cutting) was made, and is said to have exposed from 2 to 2½ feet of coal overlaid by 5½ feet of soft coaly shale. This drive has collapsed

Gully pass is approximately 5,500 feet above sea level. From it the ground descends for 550 feet to Karáta Mill (33°1′–75°5′), in the bottom of the Doodar nala, and then rises steadily for about three miles to Sukhál gully at a height of 7,400 feet.

Nearly 1,000 feet beyond Gully pass, a tunnel (drive G) was commenced in the lower shales, passed through the lower ironstone, and is said to have found indications of coal, but shortly after collapsed.

Just before Karáta Mill is reached coal is exposed at the surface for some considerable distance. The general dip is 60° to north-east. The section at this point is:—

Olive shales and nummulitic limestone	?
Coal	6′ 10″
Ironstone shales	7′
Ironstone	10′
Ironstone shales	20′
Ironstone	10
Great Limestone.	

A cutting (Karáta No. 1), now fallen in, is said to have proved the coal to be 6 feet thick at a depth of 10 feet. Three hundred feet further on, the Karàta No. 2 cutting proved the ground to a depth of 20 feet, and is said to have found the coal seam to exceed 16 feet in thickness. At Karáta Mill a drive, 30 feet in length, is said to have proved coal 5 feet 6 inches in thickness.

From Karáta Mill the strike of the beds bends round to a course 75° west of north ; the dip being north-north-east at an angle of 45.° Passing up the nala towards Sukhál gully the coal outcrop is seen to be covered up by landslips. Fragments of broken ironstone are to be seen here and there. No prospecting work has been done in this nala. About half a mile beyond Karáta Mill the rocks for some distance are seen to be contorted, the strike varying from 22° to 75° west of north.

A mile further on coal wash, two feet thick, in decomposed ironstone, occurs. The dip here does not exceed 35°.

About a quarter of a mile before Sukhál gully is reached traces of coal are found and continue right up to the top of the pass. Two hundred and fifty feet from the summit the coal seam is 2 feet 6 inches in thickness and is *overlaid* by ironstone. Evidently this is either not the true coal seam, or the latter has been repeated by a strike fault.

The Anji valley.

From Sukhál gully (33°2′—75°4′) the ground descends 3,400 feet to the bed of the Anji stream, a distance of about 3½ miles. Passing downwards the strike trends round to 45° west of north. Traces of coal are to be seen all the way down to Santráni Kund (33°2′—75°3′), about one mile from the crest. At this latter place the coal seam is 2 feet 10 inches in thickness, and dips north-east at an angle of 30°. A drive, near here, struck the coal seam at a distance of 86 feet from the start. Between this point and the face, at 350 feet, the coal averaged 3½ feet, but is very impure (see plate XII, fig. 3 for graphical representation of thickness of coal seam). For fully three-quarters of a mile further frequent exposures of the coal seam are found, but no exploratory work has been done.

About 2 miles below Sukhál gully the strike of the rocks sweeps round to the north, and the coal-outcrop becomes obscured by landslips and cultivated ground. In the bed of the Anji streams, the section exposed is :—

Murree sandstones and clays Olive shales and nummulitic limestone Coal seam	Obscured by debris.
Ironstone	6′
Shales, ferruginous at the top Siliceous grit (about 100 feet) Great Limestone.	470′

The ironstone strikes N. 5° W., and dips east at an angle of 35°. In the limestone the strike is N. 40° E. and the dip south-east at 37°.

At Kotri (33°4′—75°3′), just across the stream, the strike of the beds sweeps round to the west and continues on this course until the Anji stream is re-crossed 3 miles below. Several prospects have been

made at Kotri, but most of them, being commenced in broken ground, have collapsed. Three drives (Kotri No. I. *a*, *b*, and *c*), from 50 to 100 feet above the stream bed, were driven, respectively, 82, 40, and 45 feet, in loose ground, without finding coal. Kotri No. II drive, a short distance beyond, struck coal at a distance of 50 feet. At 57 feet the coal was said to exceed 7 feet in thickness, but the excavation has now fallen in. A companion drive (Kotri No. III) commenced in coal which thickened to 7 feet at a distance of 57 feet. This drive has also collapsed.

About a quarter of a mile further on, at Bowli (33°4′—75°3′), 450 feet vertically above the stream bed, the ironstone band is seen to be much contorted, and there are many evidences of disturbance. A drive (Bowli No. I) has been driven in near this point, for 20 feet, in soft coal exceeding 7 feet in thickness. About 500 feet beyond, an open cutting (Bowli No. II) was driven for a distance of 40 feet in coal more than 6 feet in thickness. The coal with its overlying shales dips 55° west of north, whilst 30 feet to the west the ironstone dips 75° east of north. Apparently these conflicting dips are due to surface slipping. Bowli No. III drives are 200 feet beyond No. II drive. Two drives were driven, respectively, 45 and 25 feet, in shales without finding coal. They are evidently some distance above the coal horizon. Still further on Bowli No. IV drive went 40 feet in shales containing coaly streaks. On the crest of the spur at Bourg (33°4′—75°3′), 825 feet above the Anji stream at Kotri, an open cutting has exposed a thickness of 6 feet of coal and coaly shale, striking north 78° west and dipping north at an angle of 52°. Just below this point a fault occurs—part of the old limestone being found overlying the olive shales and nummulitic limestone.

About three-quarters of a mile further west, and some 500 feet above the stream, the ironstone shales are found dipping N. 40° E., at an angle of 32°. An open cutting here (33°4′—75°2′) (Harruasu No. I) exposed 3 feet of decomposed coal. Some distance further west, two drives (Harruasu Nos. II and III) went 70 feet in the upper shales without finding coal. These prospects are quite evidently some distance above the coal horizon.

Rather more than a mile further west (in 33°4′—75°1′), a tunnel (Nadla No. III) was driven in and struck coal at 93 feet. From this point to a distance of 295 feet from the start the coal varied in thickness from 1½ to more than 9 feet, and averaged 4 feet 9 inches. At 295 feet a fault throws the measures to the south. After my last visit a crosscut in this direction was commenced, and I have since been informed that the seam, exceeding 9 feet in thickness, was reached after driving 30 feet. A sample from a point 265 feet from the portal of the drive, and where the seam exceeded 7 feet in thickness, yielded, on assay, 44 per cent. of ash. The weight of the sample was about 40 lbs. and it contained about 1½ lbs. of large, pyritic nodules. These were rejected in the assay.

From Nadla No. III drive the outcrop of the *coal measures* descends rapidly to the Anji stream at a height of 3,550 feet above sea-level. The crossing takes place at the junction of the Tote and Anji nalas. Nadla No. I drive, on the north bank of the stream was driven 30 feet without finding coal. On the south bank a drive (Nadla No. II) has exposed a mass of coal exceeding 8 feet in thickness. The *coal measures* here are much disturbed, and dip towards the north only a few degrees from the vertical. The olive shales and nummulitic limestone have thickened to 535 feet, of which thickness fully one-half consists of limestone bands. Some 60 feet south of the coal exposure the *great limestone* can be seen dipping N. 70° E., at an angle of 30°. Apparently faulting has occurred.

For rather more than a quarter of a mile from here the *coal measures* follow the southern bank of the stream, but at Hákroli they bend round sharply to the north and again recross to the northern bank. Where the crossing takes place, coal is exposed on both sides of the stream. On the northern bank a trench (Hákroli No. I) (in 33°4′—75°1′) proved the thickness of the coal to exceed 6 feet. The dip at this point is 50° in a direction 45° east of north. At a point 50 feet beyond the trench, a drive (Hákroli) has been driven in to a distance of 180 feet. Throughout its length it is in débris, with the outcrop of the coal seam appearing occasionally in

floor. As the thickness of cover increases the drive will doubtless run into solid ground. At the time of my visit the thickness of the seam could not be measured, and the coal appeared to be shaly.

Between the Anji and Chenáb Valleys.

From the Anji stream at Hákroli the Subáthu outcrops rise steadily for 1½ miles, through a vertical height of 1,700 feet, to Punchári gully (33°5′-75°0′). The dip of the beds varies from 70° to the north to 30° to the north-east. Throughout the whole of this distance no coal exposures can be seen, the lower ground being covered by cultivated fields, and the higher ground by talus.

About a quarter of a mile west of, and 350 feet below, the gully a good exposure of the ironstone and ironstone shales, dipping north at an angle of 40°, can be seen. At this point, a trench on the coal horizon exposed a V-shaped mass of shaly coal, 2 feet thick, thinning down to a few inches. Apparently a wash-out occurs, the place of the coal being taken by yellowish-gray clay. One hundred feet west another trench proved finely laminated, shaly coal, 3 feet thick, thinning to 2 feet, and dipping north at an angle of 80°. The surface dips hereabouts are extremely variable. About one-third of a mile further west, and just below the village of Bhurru, an outcrop of coaly shale containing bands of gray shale, the whole being quite 30 feet thick, can be seen. This outcrop is found 300 to 400 feet vertically below the assumed true position of the coal-outcrop, and it occurs doubtless in a slipped mass.

From Bhurru the coal-outcrop (unseen) descends into the Bhurru nala (3,800 feet), and from thence rises for nearly a mile to Malkót gully (33°6′—75°0′) (5,150 feet). About one-third of a mile from the foot of the slope the dip of the rocks is 60° north-north-east, but gradually lessens to 40°. Shaly coal is again seen about half-way up the hill. A small excavation proved its thickness to be only 2 feet, and that the deposit is extremely irregular. Near the crest of the pass the dip of the rocks is reduced to 35° north-north-east. An excavation, just over the summit, 5 feet deep, exposed soft, shaly coal exceeding 2 feet 6 inches in thickness. A little further down a trench on the coal horizon went to a depth of 9 feet in loose earth. A borehole put down

3 feet 6 inches further did not reach solid rock. Passing downwards towards the Gogu nala the following section typical of the *coal measures* north of the Anji valley was measured :—

Sandstones and clays	—
Olive shales, with bands of nummulitic limestone, ferruginous at the base	250′
Coal	variable.
Shaly ironstone	6′
Shales with ferruginous bands	350′
Calcareous shales	50′
Great Limestone.	

The dip at this point is east-north-east, 45°. An excavation in the coal seam proved shaly coal exceeding 5½ feet in thickness. A little further on another prospect showed 5 feet of shaly coal.

From the Gogu stream (4,250 feet) the outcrop of the *coal measures* rises to Gagwáni gully (5,450 feet). About a quarter of a mile from the stream, coal is exposed over a length of outcrop of 100 feet. About the same distance further on coal is again exposed in several places, in one of which a pit, 8 feet deep, proved—

Shale		—
Clay	0′	6″
Shaly coal	2′	1″
Coaly shale	2′	7″

The dip is north-east at 40°.

Half a mile beyond, at Gágwáni gully (33°7′—74°59′), the *coal measures* are much contorted, and a fine cleavage has been induced in the shales and coal. A pit, 9 feet dip, showed the coal seam to be 5 feet 4 inches in thickness. A second prospect in more disturbed ground near by proved only 2 feet of shaly coal.

Passing downwards towards the Chenáb river, coal is not seen for fully two miles. Just below Bakol (33°8′—74°58′) (2,950 feet), coal is seen in several places, but in very disturbed ground. The *great limestone* is found abutting against, and apparently overlying, the lower beds of the Subáthu group. The general dip of the rocks is south-

east, but is locally extremely variable. Probably extensive landslips have occurred here. Three excavations were made in the coal outcrop, proving shaly coal exceeding 6 feet in thickness.

In the Batrare nala, about 1 mile north-east of Bakol, coal is again found, dipping at an angle of 40° to the south-east. The seam here is about 6 feet in thickness. Further down the slope, as the Chenáb river is approached, the Subáthu group is not seen, being overlaid by débris from the higher ground.

Between Mootal and Sandráni.

Reverting to the Jungle gully area, the Subáthu beds, at Doomwa, curve round to the west as far as Mootal (32°59′—75°4′), where the Doodar river fault apparently dies out Just north of Mootal, two trenches were cut in broken ironstone showing traces of coal. In the western trench, coal 2 feet thick, dipping northwards into the hill, was struck at a depth of about 15 feet. In the Ponhias nala, which debouches between Mootal and Chirai, a shallow excavation found traces of coal. Near the temple at Chirai, a cut, 11 feet deep, showed coaly strings in a broken mixture of gray-black clay and ironstone overlaid by broken, pre-tertiary limestone. Two hundred feet further west two trenches were cut and showed similar sections. About one hundred feet south of this point, Murree sandstones are to be seen dipping vertically.

About a quarter of a mile west of Chirai, a dip drive gave the following section, dipping north-north-east at an angle of 60°:—

Brecciated limestone		?
Ironstone	3′	6″
Grey shales with coaly streaks	4′	0″
Decomposed ironstone	1′	0″
Grey clay	2′	0″
Reddish sandy clay		—

Half a mile to the north-west another excavation in similarly inverted rocks proved coal from 3 to 6 inches in thickness. Four hundred feet to the west of this excavation, a horizontal drive showed

the following rocks lying almost horizontally, but extremely irregularly:—

Limestone, broken	—
Ironstone	6′ 0″
Grey shale	1′ 2″
Coal	0′ 9″
Grey shale	0′ 10″
Red clay	4′ 0″+

At a point 1,000 feet south-west of the last excavation, and 500 feet west of Sandráni, a small detached deposit of coal occurs. The section is:—

Brecciated limestone	10′ 0″
Grey clay, containing bands of soft coal aggregating 2 feet in thickness, and a sub-angular block of ironstone, 4′×4′	4′ 0″
Red clay	1′ to 3′

This deposit is evidently derived from the outcrops further north.

About one-third of a mile west of Sandráni, a trench has exposed traces of coal in a stiff brown clay (probably decomposed ironstone) containing fragments of limestone.

In the Jagha nala, a little to the west, the Subáthu group is completely absent, the Murree beds abutting directly against the old limestone. All the way from Mootal no regular exposure of the Subáthu group occurs, the whole of the exposures showing broken and crushed rocks with frequent inversion. To the south, for more than three miles, is seen a steady succession of the Murree beds dipping from south-east to north-east at angles of from 25° to 45°. It is possible that folding with reduplication has taken place, but no evidence of such can be obtained owing to the absence of recognizable bands in these beds. Should such be the case, the coal, at certain points, may lie at a reasonable depth below the surface.

VI.

GEOLOGY OF THE SANGAR MARG FIELD.

Geology.

For a detailed description of the geology of the field the reader may be referred to Mr. LaTouche's report (Rec., G. S. I., Vol. XXI, part 2, page 62). It will be sufficient for me to say that the section of the *coal measures* is very

similar to that of the Ladda field, the two areas being actually the east and west portions of the same field. The arrangement of the outcrops at the surface is, however, somewhat different, the simple anticlinal structure of the Ladda area being replaced by a system of anticlines and synclines which add considerably to the length of the outcrops, and would facilitate the exploitation of the coal. The general arrangement of the rocks may be apprehended from an examination of the map on Plate I, and the section (fig. 1) below:—

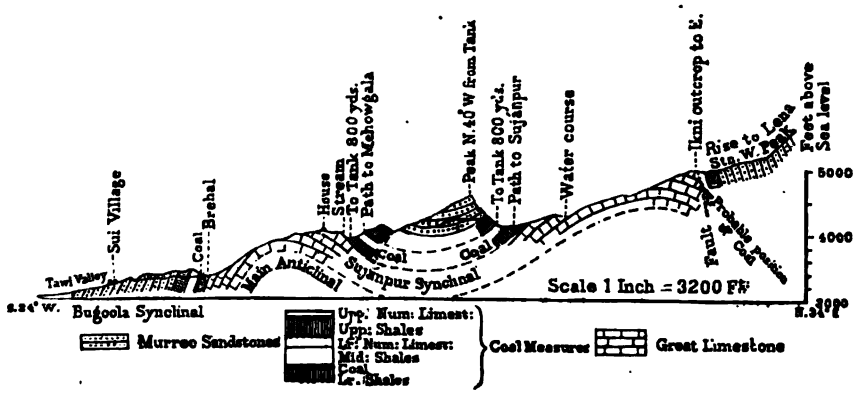

FIG. 1.—Section across Sangar Marg coal-field from Brehal to Lena Stn., on line GH on Map, Pl. I.

The above is a reproduction from Mr. La Touche's report. It is taken across the western portion of the field in a direction transverse to the strike of the rocks.

Details of the Coal-bearing Formation.—Commencing from the Chenáb river, where the description of the *coal measures* in the Ladda area was discontinued, the rocks for some distance continue to be obscured by landslips and talus deposits. Coal is first seen at Chimber (33°10′—74°57′), at a height of about 1,300 feet above the level of the river. A tunnel, 60 feet in length, was driven to prove the seam in depth. When first reached the thickness of the seam was 2 feet, but after ten feet of driving the thickness decreased to 1½ feet. The dip of the seam is

The ground between the Chenáb river and Sangar Marg.

to the north at a steep angle, and the quality of the coal is very inferior.

From Chimber the outcrops strike westward, and the horizon of the coal seam is not exposed, for fully three miles, until Kantan (33°11″—74°54′) is reached. At this point the dip of the measures is N. 15° E. at 40°. The outcrop of the seam is 4 feet thick. A tunnel proved the thickness, at a depth of 10 feet, to be 5½ feet. After my departure, the tunnel was continued a few feet further, when the seam is said to have split up into two bands, respectively 18 inches and 6 inches in thickness. The quality of the coal is very inferior. Some time previous to my visit a tunnel had been driven in at a point about a quarter of a mile further west. It is now waterlogged. It is said to have been driven to a distance of 70 feet in coal thickening from 6 to 12 inches, and that the seam disappeared in the face. From Kantan the measures continue along the northern bank of the Chenáb through Arnás (33°11′—74°52′), and cross the Ans river. Throughout this ground the measures are not exposed.

To the south of the river and about 1½ miles south of Arnás, a small outlier of the *coal measures* is found at Salár (33°10′—74°51′). The beds extend from near the river up to Salár fort, 1,500 feet above the level of the river, and 3,000 feet above sea-level. The dip is to N. 10° E. at an angle of 30°. Over most of this ground the coal seam has been denuded. Coal is seen over an area of about one-third of a mile in diameter, but the seam is variable and does not follow the same horizon for more than a few yards. The thickness varies from 2 to 5 feet, and the appearance of the coal is poor.

Returning to the main outcrop, after crossing the Ans stream the measures enter the hilly country to the north of the Radd nala. Coal is first seen at Cherungha (33°11′—74°50′), where, in the bank of the Radd stream, a cutting, 10 feet deep, exposed nearly 9 feet of coal, of which the upper half is of fair quality. This outcrop can be traced for several hundred feet to the east, but westward is obscured by talus. About a mile further west a small cutting exposed about 2 feet of coaly shale, dipping nearly vertically. From this point the measures ascend to Baldánu gully (3,000 feet), from whence they

descend for 1,000 feet into the Beddi nala, and again rise to Panásar (3,100 feet). On Panásar hill, coal outcrops are found in several places. Over a distance of about half a mile, four pits were sunk in the outcrops to depths of from 6 to 12 feet. The average thickness of coal proved was 6 feet, but it is little better than carbonaceous shale. The surface dips are very conflicting, probably due to landslipping.

In the Cheresu nala, about a mile west of Panásar, coal is again seen. A cutting proved the thickness to exceed 4 feet. A similar thickness was exposed in a cutting made at a point about a quarter of a mile to the west. In the Singar nala the coal can be traced for several hundreds of feet. A cutting, 8 feet deep, exposed the coal seam, 5½ feet thick, dipping N. 5° E. at 60°. On the western slope of the gully and about a quarter of a mile distant, two cuttings were made. In the first, coal 3½ feet thick was exposed, whilst in the second the section exposed showed two bands of coal, 12 inches thick, separated by a foot of shale. The dip is steep to the north. From here the measures can be followed through Behota (33°11′—74°45′) down to the Radd nala (2,200 feet). No coal is exposed. For about a mile the stream is followed, beyond which the beds run up the nala to the south of which lies Boni (33°11′—74°44′), to Paddar (3,400 feet). Near Boni a coal outcrop, 2 feet in thickness, is to be seen in ground which forms part of a landslip. On the way up to Paddar the measures are well shown. The shales, dipping vertically, are frequently contorted and occasionally contain coaly patches.

A little beyond Paddar the seam is again seen, dipping north at a high angle. A cutting, 10 feet deep, exposed 5 feet of inferior coal. Between Paddar and Gool (33°12′—74°40′) several cuttings and pits exposed shaly coal from 6 to 12 inches in thickness. In the village of Gool, at 4,650 feet, the seam is not less than 6 feet thick. At 5,000 feet a small cutting again exposed the seam. On the path to Ikni gully, at 5,400 feet, an irregular coal outcrop, 0—2 feet thick, is seen. On Ikni gully (33°11′—74°40′, 5,600 feet), coal is not seen, but about 100 yards to the north-west a thick coal outcrop is to be found. A tunnel was driven from a point below this outcrop, and struck coal at a distance of 108 feet. The seam is 6½ feet in thickness, and the

dip is steep to the north. The quality of the coal is good, an assay yielding only 13 per cent. of ash.

The Ikni-Sujánpur slope.

From Ikni gully the measures slant down the southern slope of the range towards Sujánpur. At a point about a quarter of a mile west of the Ikni tunnel, at a height of 5,250 feet, a thick outcrop of coal is again to be seen. The dip is vertical. A cutting to a depth of 6 feet exposed a width of 13 feet of coal. Assay showed the coal to be of inferior quality. From this point as far as Sujánpur (3,500 feet), a distance of about two miles, the measures are only occasionally to be seen, and no coal is exposed.

The Sujánpur synclinal.

At Sujánpur (33°11′—74°38′) the *coal measures* bend sharply round to the east and run towards Chakka. About a quarter of a mile from Chakka (3,900 feet) a coal outcrop 15 inches thick is seen, but cannot be traced far. Near the tank at Chakka (33°11′—74°39′) the beds bend abruptly round the eastern end of the syncline and run west. At the bend coal is exposed in several places. A cutting, 9 feet in length, in the bank of a stream, at a point 550 feet north of the tank, exposed 18 inches of coal overlaid by 5 inches of coaly shale. This cutting is situated at a point 150 feet to N. 30° E. from a pit sunk by Mr. La Touche in 1887. This pit had been filled in, but I had the débris removed to a depth of 49 feet without finding the bottom of the shaft. The coal seam is found at a depth of 41 feet and is only 15 inches thick and overlain by 6 inches of carbonaceous shale. An assay of a sample from the coal in the pit yielded 27 per cent. of ash, or 6 per cent. less than the result yielded by the coal obtained from the cutting in the outcrop. About 1,000 feet west of the tank, a drive, 9 feet in length, proved 2 feet 10 inches of coal, which on assay yielded less than 7 per cent. of ash. Five hundred feet further west the seam has thinned to 15 inches, and this thickness obtains for about 1,000 feet further to the west, beyond which point the seam appears to die out. About three-quarters of a mile from Chakka, the measures sweep round south-wards over the top of the main anticline. No coal is exposed.

At Sarodabár (33°11′—74°42′), on the top of Sangar Marg hill (5,850 feet), a small outlier of the *coal measures*, occupying the head

of Sujánpur synclinal, is found. The area over which coal is found is about a quarter of a mile in length and 150 yards in width. Coal is exposed in several places. A sample from an outcrop, more than 7 feet in width, yielded, on assay, nearly 43 per cent. of ash.

The Bugoola synclinal.

After passing down from Chakka over the top of the main anticline the coal measures again bend round to the east in the direction of Brehal (33°10′—74°37′). At the bend, in the bank of a small stream, the coal seam is excellently exposed. It is 20 inches in thickness and dips 35° in a direction S. 20° W. Two hundred yards to north-west the thickness is only 12 inches, whilst 60 yards down stream an exposure shows 2 feet of coal lying almost directly on nummulitic limestone, and dipping south-west at 45°. This unusual position of the coal is probably only explainable by faulting.

At a point 150 yards to the east, a drive exposed 3½ feet of coal dipping south-west at 43°. One hundred yards further east the seam is 4½ feet thick, whilst about 80 yards still further east only a few inches of coal is found in vertical and contorted shales. About 150 yards further on, a cutting exposed a thickness of 7 feet of coal, dipping S. 10° W. at 30°. A fault of 3 feet throw, which occurs here, probably accounts for this increased thickness, for only a few yards away a pit, 18 feet deep, proved only 11 inches of coal dipping S. 20° W. at 50°. From Brehal, the outcrops ascend the slope to the north-east for about 350 feet vertically, and from thence descend steeply to the east towards the Tawi stream. At their highest elevation (3,350 feet), and at a point where the path from Ransu joins the path from Brehal to Chakka, coal is exposed. A cutting, 6 feet deep, proved 3½ feet of coal, which on assay yielded only 4½ per cent. of ash.

On the steep descent towards the Tawi stream, coaly traces are seen in several places. A large number of cuttings exposed shaly coal varying in thickness from a few inches to 2 feet. Near the Tawi stream, at 2,700 feet, the rocks are obscured by alluvium. Near the village of Ransu (33°10′—74°38′), and about one-third of a mile east of the Tawi, a pit, 10 feet deep, exposed 4 feet of shaly coal, dipping S. 25° E. at

75°. About half a mile further east, on the top of the ridge (3,400 feet) between Ransu and Kori (33°10′—74°39′), a cutting, 5 feet deep, proved 15 inches of coal in vertical rocks. An assay of the coal yielded 28 per cent of ash. For fully three-quarters of a mile further east no coal is exposed.

At Kálamitti (33°10′—74°40′), the band of coal-bearing rocks bends sharply round the eastern end of the Bugoola synclinal, and runs back westwards. At the bend there is much disturbance of the beds, and coal is extensively exposed. In this neighbourhood, six cuttings and pits exposed coal varying from 2 to 6 feet in thickness. A sample from a cutting showing 2 feet of coal yielded 25 per cent. of ash, whilst 50 per cent. of ash resulted from the assay of a sample from a cutting showing 4 feet of coal.

In the steep nala leading westwards from Kálamitti, four cuttings exposed shaly coal from 1½ to 6 feet thick. Near the village of Krool (on map 33°9′—74°38′), the *coal measure*-rocks curve round the western end of the old limestone ridge, which here forms so conspicuous an object in the landscape, and run to the east. On the village lands a pit, 17 feet deep, exposed 4½ feet of coal which on assay yielded 35 per cent. of ash. The dip is vertical. At a point 150 yards further east, cuttings proved from 2 to 4½ feet of coal. About a mile further on, coal is again seen. It is shaly, and the beds are much disturbed. A little further east the *coal measures* are faulted down and disappear.

VII.

THE MEHOWGALA, SIRÓ VALLEY, AND KÁLAKÒT FIELDS.

The Mehowgala field.

This field is situated some 8 miles west of Sangar Marg, in 33°12′—74°32′. The coal measures occur fringing the edges of, and dipping away from, a central dome-like mass of *great limestone*, which, lying between the villages of Acker and Mehowgala, is about equally divided, on a north and south line, by the Aneari Taw stream, which passes through it in a deep and narrow gorge. Commencing on the north side, for about one-third of a mile to the eastward of the river

(2,500 feet), the measures are obscured by cultivated ground, beyond which, in the higher ground, coal is first seen. A cutting, 6 feet deep, exposed the following section :—

Coaly shale and clay	3′	0″
Coal	8′	0″
Coaly shale	1′	0″

The dip is to N. 20° E. at 65°. An assay of the coal from the 8 feet bed yielded 37 per cent. of ash.

At a point about 500 yards to south-east the seam is exposed in the high bank of the Ganoë stream. Two cuttings were made. The west cutting was driven 8 feet in a thick outcrop of soft coal of which the exact thickness and dip were not ascertained. Only 30 yards to the east the seam was found to be only 1½ feet thick, and lying almost horizontal. The coal removed from these cuttings, being intermixed with pyrites, took fire spontaneously, and burnt with a choking sulphurous odour.

At a point 350 yards higher up the stream, a pit has been sunk during former explorations. It was commenced in the shales overlying the coal seam, and, judging from the amount of spoil, must have gone to some considerable depth. Local tradition fixes the depth at about 100 feet, and does not record the finding of coal.

Some 500 feet south of the two cuttings last-mentioned, the seam was again exposed in a cutting, but the thickness is only 15 inches. One hundred yards to south-west, a drive, 10 feet long, proved coal, 2 feet 10 inches thick, dipping gently to S. 20° E. On continuing this tunnel to a distance of 14 feet, the coal gradually changed into soft shale containing thin threads of coal. One hundred yards to the west the coal seam, as proved in a 10 feet tunnel, is 3 feet thick; whilst about 50 yards still further west, the same thickness was exposed. From this point, the outcrops begin to descend towards the Aneari Taw stream, 350 feet below. About 50 yards from the highest elevation of the outcrop, a tunnel, 18 feet in length, was driven in coal thinning from 3 feet to 1 foot 10 inches, and dipping south at 20°. An assay of a sample from the face of the drive gave only 11 per cent. of ash. In a cutting 8 feet deep, some 400 feet further west, the seam is 2⅛ feet thick, and dips at 45°. Some 300 feet further on, a drive, 14 feet in length,

was made in coal thickening from 2 feet 8 inches to 3 feet. The coal from this drive is hard and of good appearance. On assay it yielded less than 8 per cent. of ash. Thirty yards further on, coal is last seen, and from this point down to the Aneari Taw, about a third of a mile, the ground is covered by talus, whilst in the bed of the stream a considerable thickness of alluvial deposits obscures the outcrops of the *coal measures*.

Between the stream and the village of Mehowgala—about half a mile—the measures are not well exposed. In two or three places a coal band, 1 foot thick, is seen in the clays underlying the coal horizon. Just below the village, the outcrops attain their highest point (3,000 feet) west of the stream. Near here, a tunnel was driven on the coal seam to a distance of 13 feet. The seam dips north at 35°, is 19 inches thick, and assays only 6½ per cent. of ash. One hundred and fifty yards to the east, a cutting, 8 feet in length, exposed coal exceeding 6 feet in thickness and dipping to the north at 20°. An assay of the coal yielded 8 per cent. of ash. From this point down to the Aneari Taw, on the east, a distance of about 300 yards, the *coal measures* are well exposed in the cliff, and coal is seen over practically the whole distance. As was occasionally observed in the Sangar Marg field, there are two seams, the upper of which varies from 6 to 12 inches in thickness, and lies about 20 feet above the lower or principal seam. The results of excavations in the lower seam, over this ground, may be summarized thus :—

Serial Number.	Distance driven, in feet.	Thickness of coal, in feet.	Dip.	Ash.
I	12	Exceeding 4		
II	21	½ thickening to 3		
III	6	2	35°	
IV	6	1¾	48°	12½ per cent.
V	12	5 thinning to 4	20°	
VI	7	2½		13 per cent.
VII	7	5½	45°	

The Siró Valley field.

About a mile to the west of Mehowgala, the *coal measures* are exposed in the broad and open valley in which Siró village (33°12′—74°30′) is situated. The general dip of the beds is to the south at a very low angle. The horizon of the coal measures is only reached at the head of the valley, in the neighbourhood of Nimbal (33°12′—74°30′), at a height of about 2,700 feet above sea level. A great deal of coal is exposed on either side of the two streams flowing through the valley, and it is not easy to correlate the outcrops. As in the Sangar Marg and Mehowgala fields, there appear to be two seams, but there are many lenticular bands of less or greater thickness.

Following the path from Mehowgala, coal is first seen at Nimbal, on the left bank of the stream which flows down the eastern side of the valley. In a drive, 30 feet in length, the thickness was 4 feet, whilst in a shaft, 22 feet deep, only a few yards away, the thickness was 3¾ feet, thinning to 3½ feet at a distance of 5 feet from the pit. In a shaft, sunk in the fields on the western side of the stream, and about 500 feet distant, the seam, at a depth of 16 feet, was 19 inches thick. Five hundred feet further up-stream, a pit, 13 feet deep, exposed a thickness of 4 feet of coal. In the centre of the valley, at a point about 1,000 feet west of the excavation last mentioned, the following section was exposed in a pit 6 feet deep :—

Coal	0′ 9″
Shale	0′ 6″
Coal	0′ 10″

On the right bank of the western stream, a good section exposes two seams of coal separated by 20 feet of shales. Short drives exposed 19 inches of coal in the upper seam, and 3½ feet of bright coal, overlaid by a foot of dirty coal, in the lower seam. About 100 yards up-stream, a cutting proved that the lower seam thins to 16 inches. In a branch nala, about 100 yards further north, the same seam is only 12 inches thick, but thickens to 2 feet, and further on is again seen with a thickness of 3 feet. About 100 yards down-stream from the

point where the two seams are exposed in one section, a cutting in the left bank exposed the lower seam, 9 feet thick, but it thins in 10 yards to 1½ feet. On the opposite bank, the seam, with a fairly constant thickness of 22 inches, can be traced for about 150 yards down-stream. On the left bank again, and about 50 yards further down, the thickness is still 22 inches. The section, at this point, exposes the interesting examples of faulting illustrated in Plate XI. About 100 yards down-stream, a tunnel, 13 feet in length, in the right bank of the stream, exposed the upper seam with a thickness of 2 feet. Assays of six samples of coal from this neighbourhood yielded ash varying from 18 to 26 per cent., but another sample, from the upper seam, gave as high a percentage as 42.

The Kálakót field.

This field is situated about two miles to the west of the Siró Valley field, and is separated from the latter by a ridge of Murree sandstone which rises to a height of about 1,500 feet above the valley. The *coal measures* are exposed on all sides of a precipitous ridge of *great limestone* which cuts obliquely across the valley of a tributary of the Aneari Taw, and is some four miles in length. The width of this ridge varies from about one and-a-half miles on the east to two or three hundred yards on the west. On the north and south, considerable local faulting has taken place, and the measures are much disturbed.

Coal is first seen at Kálakót (33°13′—74°28′), where a drive, 7 feet long, exposed 4 feet of coal, dipping N. 20° E., at 53°. Only 50 feet away, however, the seam is reduced to 14 inches. To the north-west, alluvial ground obscures the outcrops, but at Pirán (33°14′—74°27′), half a mile distant, the seam is again seen, 18 inches thick and dipping gently to north-east. About half mile further on a pit on the eastern slope of Jhaltutunia hill was sunk in coal to a depth of 14 feet. The thickness and dip of the seam were undetermined but the thickness evidently exceeds 8 feet. On the western slope of the hill, a good deal of coal is exposed. Two separate seams can be distinguished. The dip is S. 10° E., or towards the limestone, at angles of from 42° to

52°. Several excavations in the upper seams were made and a representative section of the exposures is:—

Inferior coal	1′ 0″
Shale	from 2″ to 1′ 0″
Inferior coal	1′ 0″

Over a distance of about 250 feet, three excavations in the lower seam, to a depth of from 10 to 14 feet, exposed from 2 feet 7 inches to 4 feet 3 inches of coal. Samples from this locality yielded from 12 to 17 per cent. of ash.

Between Jhaltutunia (33°14′—74°27′) and the western end of the inlier a little west of Jigni (33°14′—74°25′), a distance of about two miles, four small pits exposed a considerable thickness of coaly shale with thin inconstant bands of shaly coal. At the bend of the outcrops round the narrow ridge of limestone the beds are much disturbed, and the dips contrary. A pit, 7½ feet deep and 5 feet wide, was sunk, all in coal, without finding the floor of the seam. Just below the village of Jigni, a cutting exposed 8 inches of coal, whilst half a mile further south-east only coaly shales are to be seen. At Kargála (33°14′—74° 26′), the measures are much disturbed and the coal appears to be patchy. A pit, 7 feet deep, exposed 10 inches of bright coal; whilst 600 feet further east, 4 feet of coal was measured in a pit 6 feet deep. Between Kargála and Sonjpir (33°12′—74°27′), a distance of fully 3 miles, the rocks are well exposed but the shales contain only occasional, thin bands of coal. A little north of Sonjpir, the measures dip south-west at from 15° to 20°. A cutting proved 2½ feet of coal overlain by 6 inches of coaly shale; whilst 200 yards to the south-east, two cuttings exposed about a foot of coal overlain by a foot of shaly coal.

At a point about a quarter of a mile before the stream is crossed near Ser, the coal seam is 23 inches thick, and dips N. 70° W. at 30°. At the point where the outcrops cross the stream, a little to the north of Ser (33°12′—74°27′), three cutting sproved coal, varying from 14 to 22 inches in thickness, and dipping S. 60°W. at 15°. At a point one-third mile to the east, the beds dip S. 15° W. at 25°. A cutting exposed

lenticular bands of coal and coaly shale. Although the rocks are occasionally well exposed on the eastern side of the inlier, no coal is seen until the outcrops at Kálakót are again reached.

Seven samples of coal from this field yielded, on assay, ash varying from 11 to 33 per cent., and averaging rather more than 20 per cent.

VIII.

THE LODHRA COAL-FIELD.

Physical and Geological features.

Approximately parallel to, and some 10 miles north-east of, the Sangar Marg-Ladda anticline, another inlier of the old limestone and Subáthu beds is found.

This mass is 17 miles in length, and from one to three miles in width. It forms a lofty and precipitous ridge, cut through, three miles from its eastern end, by the Chenáb river. The following description is confined to that portion of the inlier lying on the left or south-eastern bank of the river.

As mentioned previously, the Ladda and Lodhra inliers are separated at the surface by a band of younger rocks. These rocks are extensively folded and in many places considerably contorted, the disturbance appearing to increase in intensity towards the north. It is possible that the Subáthu beds may be brought within a reasonable distance of the surface, at more than one point beneath them.

The Lodhra inlier, east of the Chenáb river, is three miles in length and one and-a-half miles in width. It is bounded on the north by the Madiál nala, and on the south and east by the Thansu and Lodhra ravines. On the south and east the Subáthu rocks are found crushed up, at high angles, against the limestone. On the north the group is missing, the Murree beds being faulted down against the limestone.

From Section No. 3, Plate IV, the somewhat simple geological features of the anticline can be clearly apprehended. From the general section, given below, it will be seen that the Subáthu group is considerably thinner here than in the Ladda exposures. It may also be pointed out that, in their turn, the Subáthu beds, at Ladda, are again thinner than the same group at Sangar Marg, as given in Mr. La Touche's

section (*Records G. S. I.*, XXI, 2), pointing to a general decrease in the thickness of these deposits towards the north and east. The general section of the rocks is as follows:—

Formation.	Description.	Thickness in feet.
Murree	Grey sandstones and red clays	Thick.
Subáthu	Olive shales	5
	Nummulitic limestone	5
	Nummulitic limestone with many shale bands	50
	Olive shales	20
	Nummulitic limestone with thin shale bands	8
	Olive shales, carbonaceous at the base	15
	Shaly coal	2—8½
	Pisolitic ironstone	3
	Brown to red, ferruginous shales	10
	Soft calcareous shales	11
Pre-tertiary	Silicious breccia	0—30
	Great limestone	Thick.

Details of the coal-bearing formation.—The highest point to which the *coal measures* attain is Simni gully (33°9′—75°10′) (7,600 feet), from whence their outcrop falls away steeply on either side to the Chenáb River (3,000 feet).

The Lodhra and Madiál nalas.

Passing down eastwards from the gully, coal is first seen in the Lodhra nala about a third of a mile from the crest. As seen at the surface, the seam is 3½ feet in thickness, lies directly on the pisolitic ironstone band, and is overlaid by 8 feet of coaly shale. An excavation (No. 4), here, gave the following section, dipping south at an angle of 66°:—

Shale	—
Shaly coal	1′ 0″
Limy shale	0′ 4″
Shaly coal	1′ 1″
Limy shale	0′ 4″
Shaly coal	3′ 6″

Shale, coming in on the left side of the drive, displaced 1 foot 6 inches of the lower coal band. Numerous angular to rounded fragments of calcareous, coaly shale were found scattered through the coal bands.

About 100 feet down the nala a small thrust fault causes considerable disturbance. Two hundred and fifty feet east of No. 4 drive,

a tunnel (No. 3) had, some time previous to my visit, been driven for 30 feet into the coal outcrop, and had collapsed. The overseer who superintended its driving stated that only coaly shale was encountered. A pit, sunk to a depth of 6 feet, showed that the tunnel had been driven above the coal seam. In the pit, 6 feet of shaly coal was proved. Two hundred and fifty feet further east, another collapsed tunnel (No. 2) is said to have been driven 50 feet in the coal. The thickness of the coal is said to have been 5 feet. A new cutting made at this point proved 5 feet of weathered, shaly coal. Two hundred feet still further down the nala, an old tunnel (No. 1), now partially fallen in, went 20 feet, and proved 4 feet of coal overlaid by 2 feet of ironstone shale, above which lie coaly shales. Five hundred feet beyond, a pit (No. 5) was sunk to a depth of 8 feet through the following beds:—

Shale	1′ 0″
Good coal	1′ 6″
Soft shale	2′ 0″
Coal	?

Owing to trouble with percolating water the sinking had to be abandoned. The rocks in the neighbourhood of this prospect are much disturbed. A dip to the south, at 75°, in a short distance alters to east at 60°. A little further on it flattens to 30°, and then increases to 48° to the south-west. From this point, although the ironstone outcrop can be followed, the coal outcrop is obscured by talus. Passing down to the junction of the Lodhra nala with the Madiál valley, the disturbance of the beds increases until just about at the debouchure (4,900 feet) the Subáthu group is faulted down and disappears. A mile down the Madiál valley, and half a mile below Madiál village (33°11′—75°11′) (wrongly marked on the Atlas sheet), the fault, striking north-west, is well shown in a spur north of the stream. The *old limestone*, dipping south-west at an angle of 85°, can be seen abutting against Murree sandstones, dipping N. 15° E. at an angle of 64°. Following down the ravine, the fault is seen to continue as far as, and beyond, the Chenáb River.

The Thansu and Kolri nalas.

Returning to Simni gully, traces of coal can be seen for some distance down the Thansu nala. In one exposure, from 3 to 4 feet of coal is seen. Prospecting is rendered difficult by huge masses of débris fallen from the silicious breccia at the base of the old limestone. Half a mile below the gully, the stream falls vertically for 12 feet over the upturned coal outcrop, which, here, measures 8 feet 6 inches of soft, bright coal, and dips south-south-east at an angle of 56°. Passing down the nala, the *coal measures* are seen to be covered by cultivated ground.

Coal is again seen about 1½ miles from the gully (at 6,000 feet), and the outcrop of the coal seam can be traced for about 100 yards. The dip, at this point, is vertical. An excavation in this outcrop gave the following section:—

Coal	1′ 0″
Irregular band of limy shale.	0″ to 6″
Coal	4′ 0″
Irregular band of limy shale	0″ to 6″
Coal, with limy concretions	3′ 0″

Below this point, the coal-bearing rocks are covered by talus from the limestone. One and three-fourths miles from Simni gully the limestone outcrop leaves the Thansu nala, rising some 700 feet up its northern slope to Kotaser gully (33°10′—75°9′) (6,050 feet). From the gully the crop descends steeply (at an angle of 30°) along the bed of the Kolri nala (33°10′—75°8′). The nala, right down to the Chenáb River (3,000 feet), is filled with débris which, in places, can be seen to exceed 30 feet in thickness. About one-third of a mile before the Chenáb is reached, the débris has been partially scoured out, and a portion of the coal seam exposed. An excavation, to a depth of 5 feet, in coaly clay, showed that all but 8 inches of the seam has been denuded. The dip here is to the south at 82°.

IX.

NATURE AND QUALITY OF THE COAL.

Physical characters.

The coal is extremely friable, slightly bituminous, and exhibits no regular bedding-planes or cleavage, but has a strongly marked foliated character. Parallel to

the foliation planes it has a bright, lustrous, graphitic appearance, but a cross-section looks dull. It is very dirty and dusty. Its specific gravity is 1·42. It burns with little flame or smoke, the proportion of the fixed carbon to the volatile products being approximately as 3½ is to 1. The ash content is almost invariably high. The coal appears to be little affected by weathering. That from the drives on the Ladda slope cokes strongly if subjected to great heat. Elsewhere, the coal only occasionally exhibits coking qualities.

From its analysis, and trials that have been made, it appears to be a fairly good steam coal. Apart from its high ash content, the worst feature of the coal is its friability. When broken, innumerable shear-planes are seen to divide the mass into thin flakes. Consequently if subjected to the least rough usage it falls to powder. Placed in water a lump of the softer coal flies to pieces like fuller's earth with almost explosive violence. This crumbling nature is undoubtedly due to the mechanical pressure to which the *coal measures* were subjected at the time of the upheaval which resulted in these rocks being brought to the surface.

In the less disturbed parts of the coal-fields, where the beds are lying at a lower angle, the coal is occasionally fairly hard. Such localities are, however, few and far between. For the above reasons, therefore, it can be understood that, where the measures are highly inclined no hope can be entertained of finding harder coal in depth.

In this state of fine sub-division Jammu coal resembles the Mákúm coal from Upper Assam, which, partly for this reason, and also owing to the large amount of sulphur it contains, is specially liable to oxidation, and as a consequence to spontaneous combustion. This latter defect does not appear to attach to the Ladda coal, for I found no trace of heating in stacks from 8 to 10 feet high. In the Sangar Marg field, however, I noticed the occurrence of this phenomenon.

Small quantities of inflammable gas, probably light carburetted hydrogen, have been, from time to time, emitted from the coal in several of the prospecting drives.

Chemical composition and calorific value.

The quality of the coal varies within very wide limits, that from the outcrops between the Anji valley and Sangar Marg, and from the Lodhra coal-field being little

better than carbonaceous shale. The following analyses of Ladda coal from the Jungle ravine were made in the laboratory of the Geological Survey of India, from samples sent down by the Kashmir Durbar officials some time previous to my first visit :—

	Gully.		Jungle.		Lain.	
	I.	II.	I.	II.	I.	II.
Moisture . . .	0·87	0·21	12·94	0·37	2·49	1·70
Volatile matter . .	17·95	15·61	37·02	15·14	45·35	15·70
Fixed carbon . .	67·66	64·38	40·80	56·15	48·52	52·06
Ash	13·52	19·80	9·24	28·34	33·64	30·54
Colour of Ash . .	Buff.	Light-grey.	Dark-brown.	Light-brown.	Light-buff.	Light-buff.
Caking properties .	Non-caking.	Cakes.	Non-caking.	Cakes.	Non-caking.	Non-caking.

Other analyses are as follows :—

	Dr. Schulten. Ladda Coal.	T. H. Ward, Esq. Ladda Coal.
Moisture	0·32	2·50
Volatile matter	14·34	11·27
Fixed carbon	67·35	83·55
Ash	17·99	2·68

The whole of the samples, from which the above analyses were made, were probably carefully selected from the best coal.

The following assays are taken from Mr. LaTouche's report on the Sangar Marg and Mehowgala coal-fields :—

	From pit at Chakka, Sangar Marg.	From pit near Bugoola, Sangar Marg.
Moisture	0·55	0·17
Volatiles, exclusive of moisture .	11·48	8·67
Fixed carbon	45·50	39·13
Ash	42·47[1]	52·03
	100·00	100·00[2].

[1] This high percentage of ash may perhaps be due to the admixture with the coal of the coaly shale band overlying the coal-seam.

[2] Agrees substantially with my own assay No. 62.

The following tabular statement gives the results of analyses made in the laboratory of the Geological Survey of India, by Sub-Assistant Hira Lal and myself, of a number of carefully-taken average samples collected by me from the outcrops and prospecting tunnels in the Jammu coal-fields.

Table of Analyses.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.	Colour of Ash.	Caking properties.
THE LADDA COAL-FIELD.													
1	Drive E, Jungle Gully.	80	Coal 1′ 2″	1	.....	0·6	10·28	51·48	32·80	4·54	...	Light-grey.	Cakes hard.
2			Dirt 0′ 2″										
			Coal 1′ 3″	2	.....	0·7	14·10	51·40	33·80	...	...	Greyish.	Ditto.
3	Ditto .	150	Coal 6′ 6″	40	433 feet from tunnel-mouth. Sample sent by Superintendent of prospects subsequently to my visit.	0·76	13·64	59·38	21·78	2·44	12·08	Ditto.	Ditto.
4	Ditto .	...	.....	3	Sample from coal shed.	0·76	14·84	44·80	39·60	...	8·80	Light-brown.	Ditto.
5	Ditto .	...	.....	4	Sample from coal shed, rough washed.	0·72	15·50	51·08	32·70	...	...	Ditto.	Ditto.
6	Ditto .	...	.....	5	Sample from coal shed, fine washed.	0·64	16·38	58·98	24·00	...	9·42	Brownish-grey.	Cakes.
7	Ditto .	...	.....	6	Dirt and coal from samples Nos. 4 and 5.	0·66	13·70	34·06	51·58	...	...	Ditto.	Do.
8	Ditto .	...	.....	41	Coke made from coal from coal shed.	0·98	0·42	69·78	25·00	3·82	...	Brown.	Hard dense coke.
9	Ditto .	547 feet from tunnel-mouth.	Coal 3′ 0″	94	.....	0·52	16·62	41·26	41·60	...	...	Grey.	Cakes hard.

* Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.	Colour of Ash.	Caking properties.
					THE LADDA COAL-FIELD—*continued.*								
10	Jungle A	405 feet from mouth of tunnel.	Coal 3′ 0″	95	.....	0·46	17·94	70·14	11·46	...	11·87	Brownish-red.	Cakes hard.
11	F drive outcrop	Outcrop	Coal 20′ 0″	39	Coked.	0·86	0·94	62·36	35·84	...	...	Light-brown.	Ditto.
12	Jungle drive	30	Coal 1′ 5″	7	.....	1·14	5·46	49·34	38·46	5·60	9·21	Brown.	Does not cake.
13			,, 1′ 8″	8	Contained an irregular clay band 4″ thick.	1·12	11·24	45·72	41·92	...		Ditto.	Cakes slightly.
14			,, 2′ 5″	9		1·00	11·68	41·06	46·26	...	...	Ditto.	Ditto.
15	Sukhál Gully	2	Coal denuded 2′ 6″	28	.....	1·78	11·62	39·74	46·86	...	...	Reddish-brown.	*Nil.*
16	Santráni Kund	2	Coal 2′ 10″	27	.....	0·76	30·38	35·06	33·80	...	...	Grey-white.	Cakes partially.
17	Ditto	264 feet from mouth of tunnel.	Coal 4′ 0″ Shale 0′ 6″ Coal 0′ 6″	92	Sample from upper band.	1·30	11·56	25·60	61·54	...	...	Brown.	*Nil.*
18	Ditto	366 feet from mouth of tunnel.	Coal 1′ 1″	93	.....	0·48	9·66	47·86	42·00	...	7·63	Grey.	Cakes poorly.

19 20 21	Bowli No. I	10	Coal 2′ 0″ „ 2′ 4″ „ 3′ 4″	10 11 12	Sample sent by the Superintendent of prospects subsequently to my first visit.	1·32 1·22 1·46	9·96 10·68 9·82	27·28 26·38 33·12	61·44 61·72 55·60	... ...	... ...	Grey. Grey-white. Ditto.	*Nil.* „ „
22	Nadla No. III	25	Coal 2′ 6″ Shale 0′ 6″ Coal 2′ 6″	42	.....	1·22	8·18	74·27	11·88	4·45	13·10	Reddish-brown.	„
23	Ditto	265 feet from mouth of tunnel.	Coal 7′ 0″	91	A sample of 40 lbs. of coal contained 1½ lbs. of large pyritic nodules. These were rejected before assay.	0·58	8·38	47·24	43·80	...	...	Brown.	„
24	Nadla No. II	5	Coal 8′ 0″ +	13	.....	2·12	10·03	79·92	6·72	1·21	13·31	Ditto.	„
25 26	Hákroli No. I	12	Coal 3′ 0″ „ 3′ 0″	14 15	....	1·20 0·96	6·78 8·24	48·07 57·24	30·50 33·56	13·45 ...	... ...	Dark-brown. Greyish-white.	„ „
27	Malkót	5	Coal 2′ 6″ +	16	.....	4·12	10·74	32·76	52·38	..	...	Brown.	„
28 29	Gogu nala	5	Coal 2′ 6″ „ 2′ 6″	17 18	....	2·34 1·78	9·46 6·94	19·12 18 14	69·08 73·14	... ...	... ...	Ditto. Reddish-brown.	„ „
30 31	Reote	5′ 6″	Coal 2′ 1″ „ 2′ 7″	19 20	....	1·32 1·10	7·96 8·16	29·28 28·56	61·44 62·18	... ...	... ...	White Ditto.	 *Nil.*
32 33	Gagwáni gully	7′	Coal 2′ 8″ „ 2′ 8″	21 22	....	1·98 1·42	8·04 6·54	26·88 30·60	63·10 61·44	... ...	... ...	Brownish Ditto	 *Nil.*
34 35	N. E. of Bakol	4	Coal 2′ 6″ „ 3′ 6″	23 24	....	4·06 2·62	8·98 6·24	16·56 22·88	70·40 68·26	... ...	... ...	Reddish-brown Light-brown	

* Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor, by Thompson's calorimeter.	Colour of ash.	Caking properties.
THE LADDA COAL-FIELD—*concluded*.													
36	Bakol	4	Coal 3′ 0″	25	.....	3·70	10·41	31·00	54·32	0·57	...	Dark-brown	*Nil.*
37			,, 3′ 0″	26		2·72	7·16	33·52	56·60	...	...	Brown	,,
THE SANGAR MARG COAL-FIELD.													
38	Chimber	30	Coal 2′ 0″	43		1·40	7·74	26·74	64·12	...	...	Grey	*Nil.*
39	Kantán	5	,, 5′ 9″	44	Said to have thinned out to two bands 18″ and 6″ thick.	1·32	3·42	27·46	67·80	...	...	Ditto	,,
40	Cherungha	3—6	,, 5′ 0″	45	.....	0·74	5·96	69·50	23·80	...	11·87	Light-brown	,,
41		6—10	,, 3′ 9″	46	.....	2·70	8·30	55·40	33·60	...	...	Brownish-red	,,
42	Panásar	0—8	,, 3′ 6″	47	.....	1·12	9·88	9·48	79·52	...	...	Ditto	,,
43		8—12	,, 3′ 6″+	48	.....	1·06	8·88	16·26	74·80	...	...	Dark-brown	,,
44	Ditto	3—9	,, 6′ 0″	49	.....	1·04	7·88	21·48	69·60	...	...	Grey	,,
45	Ditto	2—5	Coal 3′ 0″	50	.....	1·12	8·20	25·48	65·20	...	...	Light-brown	,,
46		5—11	Shale 3′ 0″ / Coal 2′ 6″+	...	Samples from coal bands.								
				51	.....	3·12	7·90	14·18	74·80	...	...	Brown	,,
47	Tákhrakót	Outcrop	,, 5′ 6″	52	.....	1·14	7·46	12·52	78·88	...	...	Reddish-brown	,,
48	Paddar	9	,, 5′ 0″+	53	.....	1·10	8·02	22·14	68·74	...	...	Brown	

49, 50	Sarodabár . .	Outcrop	Coal 3′ 6″ Coal 3′ 6″	54 55	.....	1·56 1·86	9·16 9·20	46·60 33·14	42·68 55·80	... ..	...	Ditto . . Ditto . .	„ „
51	Ikni . .	45	Coal 6′ 6″	56	.....	0·62	10·34	76·00	13·04	...	14·11	Dark-brown .	„
52, 53	Ditto . .	Outcrop	Coal 6′ 6″ Coal 6′ 6″	57 58	.....	0·58 0·76	8·78 7·70	35·60 30·00	55·06 61·54	... ...	... ...	Grey . . Ditto . .	„ „
54	Chakka . .	7	Coaly shale 0 5″ Coal 1′ 6″	59	Sample from coal band.	1·02	13·26	52·64	33·08	...	12·49	Light-brown .	Cakes.
55	Ditto . .	42	Coaly shale 0′ 6″ Coal 1′ 3″	60	Do..	0·72	13·56	58·76	26·96	...	12·69	Brown . .	„
56	Ditto . .	9	Coal 2′ 10″	61	.....	0·60	11·39	77·05	6·66	4·29	15·35	Reddish-brown .	„
57	Between Chakka and Brehal.	4	Coal 3′ 6″	62	.....	2·50	13·98	79·06	4·46	...	14·74	Brick-red .	*Nil.*
58	Kehri . . .	4	Coal 5′ 0″	63	.....	1·72	13·44	57·44	27·40	...	11·87	Ditto .	. „
59	Ponra Camp .	3—7	Coal and pyrites 0′ 6″. Coal 1′ 8″ Shaly coal 1′ 6″	64	Sample from middle bed of section.	0·78	11·08	71·28	16·86	...	13·51	Grey . .	Cakes hard.
60	Ransu. . .	10	Coal 4′ 0″	65	.....	2·68	9·92	11·68	75·72	...	...	Ditto . .	*Nil.*
61	Between Ransu and Kori.	5	Coal 1′ 3″	66	.....	17·40	20·14	34·22	28·24	...	...	Brown . .	„
62	Kálamitti . .	6	Coal 4′ 0″	67	.....	0·68	8·22	40·50	50·60	...	...	Grey . .	Cakes.
63	Kálamitti . .	7	Coal 1′ 11″	68	.....	1·18	13·26	59·84	25·72	...	12·90	Light-brown .	Cakes poorly.
64	Krool . . .	17	Coal 4′ 6″	69	.....	0·72	13·62	50·60	35·06	...	...	Grey . .	*Nil.*

Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Pl. I.	Remarks.	Moisture.	Volatile matter, exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.*	Colour of ash.	Caking properties.
			THE MEHOWGALA COAL-FIELD.										
65	Ganoé . .	6	Coaly shale 3′ 0″ Coal 8′ 0″ Coaly shale 1′ 0″	70	Sample from the middle band.	1·06	10·56	51·86	36·52	...	...	Brown . .	*Nil.*
66	Ditto . .	18	Coal 1′ 10″	71	.....	1·02	12·52	75·20	11·26	...	13·34	Grey . .	Cakes poorly.
67	Ditto . .	14	Coal 3′ 0″	72	.....	12·84	26·44	52·22	7·98	0·52	...	Brownish-red .	*Nil.*
68	Mehowgala .	7	Coal 2′ 6″	73	.....	0·78	12·64	74·94	13·04	...	13·31	.....	Cakes poorly.
69	Ditto . .	6	,, 1′ 9″	74	.....	1·48	11·76	74·20	12·56	...	13·31	Dark-brown .	*Nil.*
70	Ditto . .	8	,, 6′ 0″+	75	.....	2·80	11·94	77·50	7·76	...	13·72	Brownish-red .	,,
71	Ditto . .	13	,, 1′ 7″	76	.....	3·74	13·34	76·36	6·56	...	13·31	Dark-red .	,,
			THE SIRO VALLEY COAL-FIELD.										
72	Nimbal . .	21	Coal 3′ 9″	77	Coal thinned to 3′ 3″ in a distance of 5 feet.	1·30	11·22	69·20	18·28	...	12·90	Brown . .	Cakes poorly.
73	Ditto . .	16	,, 1′ 7″	78	.....	0·60	11·70	61·92	25·78	...	...	Ditto . .	*Nil.*
74	Ditto . .	4	Shaly coal 1′ 0″ Coal 3′ 3″	79	Sample from the lower band.	3·00	9·52	66·12	21·36	...	12·49	Brownish-red .	,,

75	Ditto	6	,,	1′ 7″	80	.....	0·74	11·14	63·34	24·78	...	11·06	Light-brown	Cakes poorly.
76	Ditto	8-10	,,	2′ 0″	81	.....	0·70	8·14	73·04	12·06	6·06	13·72	Brownish-red	Ditto.
77	Ditto	0-9	,,	4′ 0″	82	Sample from lower band.	0·80	11·84	67·34	20·02	...	13·10	Ditto	*Nil.*
			,,	5′ 0″										
78	Ditto	13	,,	2′ 0″	83	.....	0·96	10·52	46·26	42·26	...	...	Brown	,,

THE KÁLAKÓT COAL-FIELD.

79	Kálakót	7	Coal	4′ 0″	84	Thins to 14″ in a distance of 50 feet.	0·86	10·00	78·48	10·66	...	13·51	Grey	,,
80	Jhaltutunia	14	,,	6′ 0″	85	.....	0·96	10·60	71·30	17·14	...	18·90	Light-brown	,,
81	Ditto	10	,,	2′ 7″	86	.....	0·80	6·41	78·00	11·50	3·29	15·15	Grey	Cakes poorly.
82	Jigni	7½	,,	6′ 0″*	87	.....	2·58	7·76	56·74	32·92	...	12·69	Brownish-red	*Nil.*
83	Kargála	6	,,	4′ 0″	88	.....	8·98	15·70	52·40	22·92	..	...	Red	,,
84	Sonjpir	2½	Coaly shale	0′ 6″	89	Sample from the coal band.	0·76	9·64	59·08	30·52	...	...	Grey	,,
			Coal	2′ 6″										
85	Ser	Outcrop	,,	1′ 8″	90	.....	1·98	11·76	70·56	15·70	...	13·31	Grey to light brown.	,,

THE LODHRA COAL-FIELD.

86	Lodhra No. IV	6	Coal	1′ 0″	29	.....	1·32	10·96	13·20	74·52	...	...	Reddish-brown	,,
			Shale	0′ 4″										
87			Coal	1′ 1″	30	.....	1·42	9·20	11·58	77·80	...	...	Brown	,,
			Shale	0′ 4″										
88			Coal	3′ 6″	31	.....	1·30	8·82	13·32	76·56	...	...	Ditto	,,

* Pounds of water evaporated per pound of fuel.

Table of Analyses—continued.

THE LODHRA COAL-FIELD—*concluded*.

Serial No.	Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Pl. I.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor by Thompson's calorimeter.*	Colour of ash.	Caking properties.
89	Lodhra No. V	...	Coal 1′ 6″ Shale 2′ 0″ Coal ——	32	.....	0·68	6·58	54·60	32·20	6·62	...	Reddish-brown	*Nil.*
90	Kolri	5	Coal (denuded) 0′ 8″	33	.....	0·82	9·64	49·26	40·28	...	...	Brown	,,
91	Thansu nala	6	Coal 1′ 0″	34	.....	1·54	7·72	17·46	73·28	...	...	Ditto	,,
92			Shale 0′ 6″ Coal 4′ 0″	35	.....	1·62	8·70	17·80	71·88	...	...	Ditto	,,
93			Shale 0′ 6″ Coal 3′ 0″	36	.....	1·10	8·22	18·02	72·66	...	...	Grey	,,
94	Thansu nala	5	Coal 2′ 0″										
95			,, 3′ 3″	37	.....	1·32	7·46	32·42	58·80	...	...	Brown	,,
			,, 3′ 3″	38	.....	1·50	7·54	30·60	60·36	...	...	Ditto	,,

In the above table the following features stand out prominently :—

(1) The coal is extremely variable in quality, the samples from the outcrops between the Anji valley and Sangar Marg, and from the Lodhra coal-field being little better than carbonaceous shale.

(2) The volatile content is almost invariably low.

(3) The sulphur content is somewhat high.

(4) The coal is only occasionally of a caking quality.

Burning Tests.

A reference may be made here to a series of comparative tests of Bengal coal, firewood, and Ladda coal.

The tests were made in the water-tube boilers at the Jammu water-works. The boiler draught was induced by steam jets placed below the fire bars. The briquettes used in the experiments were made from Ladda dust coal and rice paste, were compressed in a small hand press, and were sun-dried. They had the following composition :—

Dust coal	100 parts.
Rice meal	2½ „
Water	1¼ „

They were extremely soft, and crumbled easily through the fire-bars. The following table gives the details of the tests : —

Summary of comparative burning tests at Jammu waterworks.

Serial number.	Coal from	Variety of fuel.	Spacing of fire-bars.	Maunds burnt per hour.	Stoking details.	Percentage of ash and cinder.	Heat value, Bengal coal being 1.	Remarks.
1	Bengal .	Hard lump .	½"	2·43	Thrice during 8 hours.	26½	1	
2	...	Selected hard, dry firewood.	½"	6·01		...	0·40	
3	E. drive .	3"—6" lumps	½"	2·66	„	23½	0·91	
4	„ .	¾"—2" nuts .	½"	2·66	„	36½	0·91	
5	„ .	Briquettes .	½"	3·83	Every hour	39½	0·54	
6	Lain drive	3"—6" lumps, soft.	½"	4·69	„	43½	0·52	
7	„ .	Briquettes .	½"	3·91	„	29½	0·62	Coal dropped through the fire-bars.
8	Jungle drive	„	½"	5·06	„	33½	0·48	
9	„ .	Coal dust .	3/16"	7·20	Thrice every hour.	61	0·34	

During the last six months a number of experiments have been made with Ladda coal in the locomotives on certain sections of the North-Western Railway. Through the courtesy of the Manager, Mr. S. Finney, I have been supplied with details of the trials, which are given in a condensed form in the subjoined table. For purposes of comparison the details of trials with Dandót and Bengal coal are also given.

Details of locomotive trials with Ladda, Dandót and Bengal coal on the North-Western Railway.

Serial No.	Date.	Runs were between	Miles run.	Average speed in miles per hour.	Average weight of train.	Description of fuel.	Pounds of fuel used per ton-mile.	Pounds of water evaporated per pound of fuel.	Remarks.
1	8th to 13th July, 1903.	Lahore and Lala Musa.	493½	22·5	353	Ladda coal 94 % Pitch in briquettes 6 %	0·11	6·53	No clinker.
	3rd to 5th and 7th September, 1903.	Lala Musa and Kundián.	628	25	259	Ditto.	0·15	6·52	
	14th to 19th July, 1903.	Lahore and Lala Musa.	493½	21·5	336	Ladda coal 96 % Meal 3 % Lime 1 % in briquettes.	0·16	5·11	Briquettes extremely fragile. After rain a stack of 10 tons was reduced to pulp. Clinkered slightly.
	2nd to 17th July, 1903.	Ditto	493½	23	300	Ladda coal 97 % Lime 3 % in briquettes.	0·17	5·06	In transit from factory at Harappur to Lala Musa (51 miles) 25% of the briquettes crumbled to dust. During trial 10% of specially-selected briquettes crumbled to pieces. Clinkered badly.
5	23rd January, 1904.	Lala Musa and Makarwál.	45	19	230	Ladda coal 92 % Pitch 8 % in briquettes.	0·34	3·45	Coal and clinker obstructed fire bars. Average steam pressure only 80 pounds per square inch. Two hours' time were lost on run. Briquettes extremely soft and much worse than those with 6% only of pitch. 32 % crumbled to dust during transit from factory.
6	20th to 28th July, 1903.	Lahore and Lala Musa.	493½	21·5	339	Dandót coal 92 % Pitch 8 % in briquettes.	0·18	4·57	Trials made in wet and windy weather. Clinkered badly.
7	4th March, 1902 to 27th June, 1903.	Lahore, Phillour, and Lala Musa.	9,040½	24·4	306	Coal from 15 Bengal collieries.	0·136	6·05	

The briquettes of Ladda and Dandót coal used in the trials were made in the North-Western Railway Company's briquette factory at Haranpur.

As far as actual fuel consumption is concerned, Ladda coal, except in test No. 5, showed up exceedingly well. In every test, except the one just mentioned, it was superior to Dandot coal, and in one test it was actually considerably superior to Bengal coal. Great trouble was, however, experienced in burning the coal properly owing to the fragility of the briquettes, and this became so accentuated in the final test (No. 5), when briquettes made with 8 instead of 6 per cent. of pitch were used, that the experiment had to be abandoned before one-third of the contemplated run had been completed. The engineers who conducted the trials subsequently gave it as their opinion that unless some more suitable binding agent can be employed Ladda coal is unfit for steam-raising purposes in either locomotive or stationary boilers. This severe verdict is no doubt justified by the trials, but I am distinctly of the opinion that a suitable bond can be found. I would draw special attention to my No. 9 experiment in the table on page 242 in which a mixture of 95 per cent. coal and 5 per cent. wheat flour was used. Bulk experiments might be made with this bond, and with a composite bond of pitch and wheat flour. Again, seeing that briquettes made with 6 per cent. of pitch were so much superior to those made with 8 per cent. of that material, it would be interesting to see if a further improvement might result from a still further reduction of the percentage of pitch.

Briquetting.

From its finely divided condition there is considerable difficulty in using Jammu coal in the ordinary fire-grates of steam boilers. It will, therefore, probably be found imperative to compress the coal into briquettes. For this purpose, owing to the small amount of bituminous matter and moisture contained in the coal, some binding material will be necessary. Such bond should add as little as possible to the already high ash content. Probably pitch would be the most suitable bond, but unfortunately it is a somewhat expensive one.

With the object of utilizing some cheaper material, I have made a number of briquetting experiments with different binding materials. The coal used was passed through a screen with apertures $\frac{1}{11}$ inch diameter, was then mixed with the bond, and water added until the mixture took the impress of the fingers when squeezed in the hand. The paste was then placed in a wooden mould, and compression applied through a flat piece of wood by blows from a hammer. The briquettes were afterwards dried in the sun. The defects in this method of manufacture are:—

(1) The paste was not steam-heated.

(2) The compression applied was quite insufficient—a pressure of about 2 tons per square inch being required.

The dimensions of the briquettes were 3″ × 3″ × 4″. Their resistance to an endways compressive strain was determined in the testing machine at the Sibpur Engineering College,* and as a result of these experiments, I am of the opinion that satisfactory briquettes can be made from Ladda coal. Before importing briquetting plant, however, about 5 tons should be shipped to some makers of briquetting machinery for an opinion as to the most suitable bond.

In the following table, details of the briquetting experiments are given:—

Details of briquetting experiments.

Serial number.	Composition.		Pressure, in lbs. per square inch, under which a briquette broke when placed on end in the testing machine.	Result of burning trial, and remarks.
	Coal.	Bond.		
1	100 parts.	2 parts of lime .	Soft	B.
2	100 parts.	3 parts of lime .	„	
3	100 parts.	4 parts of lime .	„	

* I have pleasure in expressing my obligation to the College authorities and particularly to Mr. W. H. Everitt, the Professor in Engineering, for kindly assistance in carrying out the tests.

Details of the briquetting experiments—continued.

Serial number.	Composition.		Pressure, in lbs. per square inch, under which a briquette broke when placed on end in the testing machine.	Result of burning trial, and remarks.
	Coal.	Bond.		
4	100 parts.	3 parts of lime. 1 part of "mah" meal.	82	
5	100 parts.	2 parts of lime. 2 parts of "mah" meal.	97	
6	100 parts.	1 part of lime. 3 parts of "mah" meal.	162	Burnt freely with small amount of yellow flame. Cracked in furnace but did not break up.
7	100 parts.	5 parts of pounded mustard seed.	87	
8	100 parts.	5 parts of oil cake made from mustard seed.	117	
9	100 parts.	5 parts of wheat flour.	226	
10	100 parts.	7½ parts of liquid tar.	11	
11	100 parts.	10 parts of liquid tar.	15	
12	100 parts.	2 parts of liquid tar. 3 parts of oil cake.	9	This poor result is to be accounted for by the fact of the mixtures not being steam heated before manufacture.
13	100 parts.	2 parts of liquid tar. 3 parts of wheat flour.	28	
14	97 parts.	3 parts of lime.	97	
15	94 parts.	6 parts of pitch.	244	Machine-made in the North-Western Railway Co's. factory at Haranpur.
16	92 parts of Dandót coal dust	8 parts of pitch.	163	
17	90(?) parts of Welsh coal dust	10(?) parts of pitch.	1,653	Specially made for storage purposes on the North-Western Railway.

Washing.

The quality of the coal might easily and cheaply be improved by subjecting it to a washing process. With the object of ascertaining if this could be successfully done I made experiments in a roughly-constructed washer on the trough principle. This machine consisted of a wooden trough, 24 feet in length, 8 inches deep, and 8 inches wide. At intervals of about 5 feet wooden "riffles" or partitions, 5 inches in height, were fixed in the trough. It was placed in position with a slope of about 1 in 15. A stream of coal and water was then led into the upper end of the trough, and passed through it, rising successively over each riffle. At the same time the coal was raked backwards towards the upper end of the trough. By this means a concentration of the heavy dirt took place behind the riffles, whilst the lighter coal passed on out of the trough and was collected over a fine-meshed screen. The coal experimented with contained 39·6 per cent. of dirt, and this was reduced by the washing to 24 per cent.

It may be remarked that, depending as it does upon the difference in the specific gravity of the lumps of coal and dirt, coal washing can only be successful when the coal is separated by a screening operation into lumps of equal size, of which each size is washed separately.

In the above-described experiments unsized coal was used and consequently the result achieved—a reduction of the amount of dirt by 40 per cent.—is by no means an unimportant one. I am, therefore, of the opinion that, with careful sizing, Ladda coal might be satisfactorily washed in trough washers on a large scale. The trough washer is the cheapest in first cost, and simplest of the numerous types of coal-washing machines.

Coking.

Whilst in the field I made a number of coking experiments * with Ladda coal from E drive. The oven used was roughly constructed of

* I have pleasure in expressing my thanks to Mr. J. Godwin, the officer in charge of the coal prospecting operations, for his valuable assistance in carrying out the washing, briquetting, and coking experiments.

undressed stone, plastered with mud. The waste gases were passed through a straight, iron pipe, 32 feet long, cooled externally by running water. The coking occupied about three days. Owing to my not having time to personally superintend the varying admission of the air-supply to the oven, the fire became extinguished before the coking was complete. Two experiments were made, the resulting product, in both cases, being large lumps of fairly hard, three parts coked coal. The condensation products were chiefly water obtained from the evaporation and subsequent condensation of the water contained in the mud used in plastering the oven-walls. On the top of the water floated a skim of light oil. No tar or heavy oils were obtained.

In a third experiment, coal dust was placed in a galvanized iron pipe, pierced with small holes, which was heated in a furnace. In still another experiment, a drum of wrought steel, a sixteenth of an inch thick, was substituted for the pipe. The coke obtained from both experiments was hard, dense, and grey in colour. Some pieces, however, were bright and silvery.

The conclusion that may be drawn from these experiments is, that a serviceable foundry coke can be made from Ladda (E drive) coal. Greater heat, however, is required in the coking than is necessary in the case of most coking coals. As a consequence, flue ovens, as opposed to those of the bee-hive type, would be necessary.

X.

THE WORKABLE AREAS AND THE QUANTITY OF FUEL AVAILABLE.

When in the field together, Messrs. Oldham, Hope, and the Writer arrived at the conclusion that the existence of a continuous seam of coal in the Ladda coal-field, between Jungle gully and Hákroli (in the Anji valley), was fairly well proved. At the same time, owing to the great variability in the thickness of the coal seam, we did not think that sufficient evidence had been obtained to enable an authoritative opinion as to its workability to be given. In order to decide this

point we agreed that a number of drives, not less than 500 feet in length, should be driven in from certain selected points on the outcrop of the seam.

On my second visit to the Ladda coal-field, I had an opportunity of visiting these drives and making the observations necessary for the forming of an opinion. These observations are summarized in the following table:—

Results of the long drives in the Ladda field.

Locality and name of tunnel.	Distances between which measured sections at 5 feet intervals were taken.	Average thickness of coal.	Remarks.
Jungle gully, Drive A	from 90′ to 320′	1′ 11″	
Ditto . .	from 320′ to 435′	2′ 3″	
Jungle gully, Drive E.	from 70′ to 550′	3′ 0″	
Jungle gully, Drive F.	from 0′ to 32′	8′ 0″	
Ditto . .	from 32′ to 145′	0′ 0″	
Ditto . .	from 145′ to 302′	0′ 9″	
Santráni kund, in the Anji valley.	from 86′ to 350′	3′ 6″	Coal too impure to be workable.
Nadla, in the Anji valley	from 93′ to 295′	4′ 9″	Coal is in bands with shale between.
All drives . .	1,329 feet of driving	2′ 7″	Neglecting the figures for the Santráni kund drive.

From which it can be seen that for 1,329 feet of driving on the coal seam the average thickness of coal was 2 feet 7 inches; a thickness which may, perhaps, under the circumstances, be considered just workable.

Although every effort was made to preserve the original direction of the drives, yet, on account of the variable strike, they are most tortuous, right angle bends being frequent. For this reason great difficulty was experienced in fixing the ventilating pipes and in getting out the coal from the working-face to the surface.

Division of the coal areas.

It will be convenient, for the purpose of estimating the quantity of fuel available, to divide the coal-fields into the following areas:—

A.—The Ladda and Sangar Marg coal-fields.

(1) The area from which coal might be brought to a railway with terminus at the foot of the Ladda slope.
  (*a*) The country south of Sandráni and Mootal.
  (*b*) The Ladda slope.
  (*c*) The Sukhál gully southern slope.
(2) The area from which coal might be brought to a railway aligned along the Anji valley.
  (*a*) The slope from Sukhál gully to the Anji stream.
  (*b*) The northern slope of the Anji valley.
(3) The ground between the Anji valley and Sangar Marg.
(4) The Sangar Marg (Ikni Krool) area.
  (*a*) The Ikni-Sujánpur slope.
  (*b*) The Sujánpur synclinal.
  (*c*) The Bugoola synclinal.

B.—The Mehowgala field.
C.—The Siró valley field.
D.—The Kálakót field.
E.—The Lodhra field.

Considering these areas in the above order:—

A.—The Ladda and Sangar Marg fields.

(1) *The areas from which coal might be brought to a railway with terminus at the foot of the Ladda slope.*

(*a*) *The country south of Sandráni and Mootal.*—Excavations on a line between Sandráni and Mootal have failed to prove the existence of a workable coal-seam. To the south a steady succession of the beds overlying the coal measures, dipping from north-east to south-east at angles of from 25° to 45°, is seen for several miles. It is possible that folding has repeated these outcrops, and that at certain points the *coal measures* may have been brought up within a reasonable distance from the surface. This could only be ascertained by boring operations.

The only advantages which would attach to the working of coal in this area would be its closer proximity to markets, and the avoidance of the inclines or ropeways which will be required for bringing down the coal from the mines in the hills. It does not appear likely that the coal will be found in any better physical condition than in the hill areas, and the slightly lower angle of dip would certainly render its working no more simple.

The disadvantages are apparent. The whole of the working would be to the dip, necessitating a heavy capital expenditure on deep shafts and pumping plant. The output obtainable from any pair of shafts would, owing to the comparatively high dip of the seam, be small. Under these circumstances I consider that it would be distinctly inadvisable to incur any expense in the search for coal in this locality.

(*b*) *The Ladda slope.*—Between Mootal and trial trench No. I, the *coal measures* are so much disturbed that the coal could not be profitably exploited. From the latter point to Karáta mill, a horizontal distance of about 2½ miles, the existence of a probably workable seam of coal, averaging 2 feet 2 inches in thickness,[1] has been fairly well proved.

The height from trial trench No. I to Gully pass is 1,643 feet, and the fall from the latter point to Karáta mill is 559 feet. The average dip of the seam is 45°. Allowing for a loss in working of 30 per cent., the amount of coal which might be extracted from above free drainage level is, therefore[2]:—

$$\left(\frac{12{,}148 \times 1{,}643 \times 13 \times 1.414}{2 \times 25 \times 6} - \frac{2{,}552 \times 559 \times 13 \times 1.414}{2 \times 25 \times 6}\right) \times \frac{7}{10}$$

$$= 795{,}029 \text{ tons.}$$

[1] Calculated from table on page 245.

[2] This calculation and those following involve the following factors—

$$\frac{A \times B \times C \times D \times E}{F}$$

Where—

A = Horizontal distance in feet.
B = Vertical „ „
C = Thickness of seam „
D = Co-secant of the angle of dip.
E = Fraction workable.
F = 25=Number of cubic feet in one ton of coal.

(*c*) *Sukhál gully, southern slope.*—No prospecting work has been done in this area. A drive near the bottom of the slope is said to have proved coal exceeding 16 feet in thickness. At the top of the slope an outcrop of coal 2 feet 6 inches thick is seen, but it is doubtful if this is the true coal-seam. Presuming, however, that the seam underlies this area and is workable, then the quantity of coal above free drainage level, assuming an average thickness of 2 feet 7 inches, and a working loss of 30 per cent., would be:—

$$\frac{6{,}600 \times 2.460 \times 13 \times 1.414 \times 7}{2 \times 25 \times 10 \times 6} = 696{,}383 \text{ tons}$$

This estimate includes only the coal lying above the level of Karáta mill, at the foot of the slope. Should it be found possible to drive roads through from the lowest workable point on the Ladda slope to work the deeper-lying coal on the Sukhál slope, then the above estimate would have to be increased by 613,730 tons.

(2) *The area from which coal might be brought to a railway aligned along the Anji valley.*

(*a*) *The slope from Sukhál gully to the Anji stream.*—The quality of the coal obtained from the long drive at Santráni kund is so disappointing (two samples yielded, respectively, 42 and 62 per cent. of ash, although an outcrop sample gave 34 per cent.) that I do not think this area should be reckoned upon.

(*b*) *The northern slope of the Anji valley.*—Over this ground the amount of ash in the samples taken varied from 6·72 to 61·44 per cent. As far as quality goes, parts of this area may be considered workable. In regard to the conditon of the seam the evidence is not so satisfactory. Faulting and frequent contortion of the rocks have taken place. On this account it will be prudent to count upon an extraction of only 50 per cent. of the seam. The distance along the Anji valley, horizontally, is about three miles. The average thickness of the seam may be taken as not less than 4 feet, with an average dip of 40°. The average height above the stream-bed is probably about 500 feet. On these assumptions the amount of workable fuel above free drainage level will be;—

$$\frac{15{,}840 \times 500 \times 4 \times 1.5 \times 5}{25 \times 10} = 950{,}400 \text{ tons.}$$

Between the Anji stream and Punchári gully, no coal is exposed at the surface. A single drive near the stream-bed proved coal, exceeding 6 feet in thickness, which, on analysis, yielded 32 per cent. of ash. It is possible that the seam may continue of workable thickness and quality as far as Punchári gully. The horizontal distance is about 7,000 feet and the maximum height 1,700 feet. The seam has an average dip of 45°, and may prudently be presumed to be only 3 feet in thickness. Allowing for a working loss of 30 per cent. the amount of coal available above free drainage level will be:—

$$\frac{7{,}000 \times 1{,}700 \times 3 \times 1{\cdot}414 \times 7}{2 \times 25 \times 10} = 706{,}717 \text{ tons.}$$

(*3*) *The ground between the Anji valley and Sangar marg.*

With two exceptions the analyses of the samples from this area are uniformly bad, the ash varying from 52 to 80 per cent. The exceptions referred to are the analyses of the samples from the cutting at Cherungha in the Radd nala, about 1¼ miles west of Arnás, which yielded from 24 to 34 per cent. of ash. I do not think, however, that the exceptional result from this drive is important, for apart from the question of quality, the seam appears to be too inconstant in thickness to be workable. I have little hesitation, therefore, in condemning the whole area.

(*4*) *The Sangar Marg (Ikni-Krool) area.*

(*a*) *The Ikni-Sujánpur slope.*—The only exposures of coal are near Ikni at the summit of the hill. Assay results are conflicting: coal from a tunnel gave 13 per cent. ash in a sample from a point where the seam was 6½ feet thick, whilst samples from an outcrop 13 feet thick yielded, respectively, 55 and 62 per cent. of ash.

Between Ikni and Sujánpur the possible occurrence of a fault throwing down a portion of the *coal measures* is mentioned by Mr. La Touche (*Records, G. S. I.*, vol. XXI, part 2, p. 66), but I was unable to find any positive evidence of such, and taking into consideration the thinness and frequent absence of the coal seam in the Sujánpur syncline, I think it must be concluded that the seam is absent over this ground. This area, therefore, may be considered unworkable.

(*b*) *The Sujánpur Synclinal.*—Over this ground the seam, except in one place, is too thin to be workable. The exception occurs at a point near Chakka where the coal is nearly 3 feet thick, and yields only 7 per cent. of ash. On either side, however, the coal thins in a short distance to 15 inches.

In the small outlier on the crest of Sangar Marg hill at Sarodabár, the quality of the coal is too poor, the quantity too small, and the locality too difficult of access for the deposits to have any economic value. On general grounds, therefore, this area must be condemned as a coal producer.

(*c*) *The Bugoola Synclinal.*—From Brehal as far as Kálamitti the quality and thickness of the coal is too variable to afford any hope of its being profitably mined. On the southern side of the syncline a considerable thickness of coal is exposed in several places, but it is found that wherever the seam exceeds about 2 feet the quality of the coal is inferior. I have little hope, therefore, that mining in this area would prove to be commercially successful.

B.—The Mehowgala Field.

In this field the quality of the coal is undoubtedly good. The thickness of the seam is, however, extremely variable. The height of the outcrop maintains a fairly general level, and practically no coal is available above free drainage level. In order to work the coal deep shafts and probably heavy pumping would be necessary. Under these circumstances I am distinctly of the opinion that mining on an extensive scale would not be profitable.

C.—The Siró Valley Field.

This field is the most promising of those on the west of the Chenáb. The quality of the coal appears to be, on the whole, fairly good. Its thickness, as elsewhere, is variable, but may be considered, as a rule, workable, seeing that the low dip of the beds to the south would allow of free drainage. I do not consider that any reliable estimate of the quantity available can be given, but taking the length of the roughly semi-circular outcrop as one mile, and presuming that the thickness of the coal averages 2 feet, and that a 70 per cent. extraction might be

made, the amount available, within half a mile of the outcrop, would be rather more than three-quarters of a million tons.

The distance of the field from the railway terminus at Jammu (40 miles direct, over very difficult country) renders it extremely doubtful whether the profit from the working of the coal would ever repay the capital expended upon the construction of a railway line.

D.—The Kálakót Field.

Although the quality of the coal in this field is marketable, yet its variability in thickness, the disturbed condition of the rocks, the necessity for deep shafts and pumping, together with the difficulty of access, render it impossible to look upon the exploitation of this field as a commercial venture with any prospect of success.

E.—The Lodhra Coal-field.

The analyses of the samples of coal from this locality vary in amount of ash from 59 to 78 per cent., exclusive of a sample (No. 89), from a band of coal 1 foot 6 inches thick, giving 32·2 per cent. of ash, and of a sample (No. 90), from a denuded outcrop 8 inches thick, showing 40·28 per cent. ash. In the face of these facts I am unable to recommend that any capital should be expended in opening up this field.

Summary of estimates.

Summarizing :—

The amount of coal which might be brought to a railway aligned to the foot of the Ladda slope is seen to be :—

	Tons.
Probable yield (from A, (1), b)	795,029
Possible yield (from A, (1), c)	696,383
Possible yield (from A, (1), c)	613,730
	2,105,142

The amount of coal which might be brought to a railway aligned along the Anji valley is:—

	Tons.
Probable yield (from A, (2), b)	950,400
Possible yield (from A, (2), b)	706,717
	1,657,117

These estimates include only the coal which might be worked from above free drainage level. Should it pay to establish pumping and hauling plant, they would be considerably increased.

XI.

ECONOMIC ASPECTS OF THE COAL QUESTION.

Market value of Ladda coal.

Before entering upon the consideration of the above subject it will be necessary to consider what the selling value of the coal will be. I am of the opinion that washed and briquetted Ladda coal will have an equal, if not a greater, value than Bengal coal.

Now at Wazirabád Station, the junction of the Tawi branch of the North-Western Railway with the main line, Bengal and Ladda coal would enter into competition on equal terms for all places north and west of that place. From data which have been supplied by the officials of the North-Western Railway Company, I have calculated that the average cost of Bengal coal delivered at Wazirabad is Rs. 19-11-8 per ton. In the following calculations, therefore, I propose to estimate the probable cost per ton of landing Ladda coal at Wazirabád and, to consider the difference between this sum and the amount Rs. 19-11-8 as profit or loss.

As has been already shown, there are two areas in which coal possibly workable at a profit occurs. These areas are—

(1) The Ladda slope, approached through Tikri and Mootal.

(2) The Anji valley, approached through Riássi and the valley of the Anji stream.

Most favourable position for a colliery.

For both of these areas the final outlet to existing markets must be through the North-Western Railway Company's line connecting Jammu (Tawi) with the Company's main line at Wazirabad. Should it be decided to commence the working of coal in only one of these areas, undoubtedly the Ladda slope should be chosen, because the cost of transport to Tawi from the Anji valley area would exceed the cost of transport from the Ladda area to the same place by more than 40 per cent. The alignment of the Jammu-Kashmir line would, however, affect this question.

Probable output of coal.

Presuming, then, that a colliery is to be established on the Ladda slope, the first point to be decided would be the probable output which may be counted upon. Mr. Hope estimated this at 400 tons a day; which for 300 working days would be 120,000 tons per annum. This amount is probably somewhat in excess of the amount which a 2′ 6″ gauge railway could carry, presuming that 12 trains, with an average load of 27 tons (Mr. Weightman's estimate [1]), could be run daily. Taking into consideration this fact and the fact that there would probably be difficulty in obtaining suitable mining labour, I am inclined to consider Mr. Hope's estimate somewhat high. I propose, therefore, to base my estimates on a presumed output of 50,000 tons per annum.

A.—Estimates for the Ladda Slope.

	Rs.
Cost of 2′ 6″ gauge railway from Mootal to Tawi (Mr. Weightman's estimate)	31,00,000
Interest and depreciation on 31 lakhs at 11 per cent.	3,05,000
Working expenses on the carriage of 50,000 tons of coal at the rate of ¼ pie per maund per mile (Mr. Weightman's rate)	58,333
	3,63,333
Deduct—Earnings on account of ordinary local traffic (Mr. Weightman's estimate)	56,039
	3,07,294

Cost per ton for transport of 50,000 tons of coal to Tawi $= \frac{3,07,294}{50,000} =$ Rs. 6-2-4

The actual cost per ton for washing coal in a number of European plants has been calculated to be as follows:—

	Cost per ton, in pence.
Lührig washer	1·98
Murton washer } modified trough types	0·79
Elliott „ } modified trough types	0·76
Trough washer	0·88
	3·00

The greater cost of coal-washing in a trough machine is due to the large amount of labour required. With cheap Indian labour, trough-washing would probably be as cheap in working cost as any other system, and there is the additional advantage that the capital cost is extremely low. No expensive machinery need be imported from Europe, as would be necessary in the case of the more elaborate

[1] Report on the Kashmir Railway.

systems of washing. The whole of the construction would not be beyond the powers of native carpentry.

The cost per ton of making Dandot coal briquettes in a plant at Haranpur, for an output of 20 tons, has been estimated to be Rs. 6-0-0.

The average cost per ton in a number of European plants briquetting 100 tons per day has been calculated to be Rs. 2-7-0.

This latter figure would be increased by the enhanced price of pitch in India to Rs. 2-14-0.

With a plant briquetting about 250 tons per day, the economy would be much greater than in a small plant such as that at Haranpur or even in the case of the 100-ton European plants.

Allowing a margin of one-third over the European cost for the increased expense of operating a plant in India, the cost per ton of washing the coal and manufacturing it into briquettes with pitch should not exceed Rs. 4-0-0 (2).

The cost of mining coal under somewhat similar conditions at Dandot Colliery is said to be Rs. 6 per ton. Owing to the softer nature of the Ladda coal, probably the actual getting cost would be less than at Dandot, but on the other hand the cost for dead work would be much greater owing to the more disturbed condition of the seam. Taking these facts into consideration, I am inclined to think the mining cost per ton would not be less than Rs. 9-0-0 (1).

A reduction by 20 per cent. due to the removal of the dirt would add to the mining cost per ton by Rs. 2-4-0 (3).

ESTIMATE NO. I.

For an output of 50,000 tons per annum.
(*Ladda slope.*)

	Cost per ton. Rs. a. p.
Mining (1)	9 0 0
Washing and briquetting (2)	4 0 0
Loss by reduction of dirt in coal (3)	2 4 0
Interest and depreciation at 11 per cent. on capital required for the development of the colliery, say, 4 lakhs	0 6 4
Management and offices	0 6 0
Transport to Tawi (4)	6 2 4
Transport from Tawi to Wazirabad	0 11 0
	22 13 8
Selling price at Wazirabad	19 11 8
Loss per ton	3 2 0

A loss of Rs. 3-2-0 per ton would give an annual loss of Rs. 1,68,750, which, on a capital of 35 lakhs, would amount to 4·8 per cent.

From a knowledge of the present state of the investigation for the alignment of the proposed Jammu-Kashmir Railway, there appears to be little chance of the route followed passing within reasonable distance of the Ladda slope, and consequently no relief in transport rates can be hoped for from the building of that railway.

Bullock traction.

It has been proposed, however, to work the coal-line between Mootal, at the foot of the Ladda slope, and Tawi by means of bullock traction, and to utilize the existing cart-road between Tawi and Udhampur. The representatives of a well-known engineering firm have visited the neighbourhood and reported most favourably upon such a project. Their estimate for supplying the rails, wagons, etc., necessary for a line designed to carry 500 tons of coal per day, amounts to nearly 4½ lakhs. Using this estimate, the cost of a line worked by bullock traction and designed to carry a maximum of 250 tons per day would be approximately:—

	Rs.
Formation between the cart-road at Tikri and Mootal, 10 miles at, say, Rs. 40,000 per mile	4,00,000
Rails, wagons, plant, etc., for 50 miles	3,00,000
Sleepers, 2,000 per mile, at As. 12 each	75,000
Laying rails, at Rs. 500 per mile	25,000
Ballasting, at Rs. 500 per mile	25,000
800 bullocks, at Rs. 30 each	24,000
Total cost of line	= 8,49,000
	or say, 8½ lakhs.

	Rs.
Interest and depreciation on 8½ lakhs, at 11 per cent.	93,500
Carriage of 50,000 tons of coal, at ½ pie per maund per mile	58,333
Earnings on account of ordinary local traffic	56,039
	2,07,872
	say, 2 lakhs.

Cost per ton for transport of 50,000 tons of coal from Mootal to Tawi $= \frac{2,000,000}{50,000} =$ Rs. 4.

ESTIMATE NO. II (LADDA SLOPE).

Substituting this amount Rs. 4 for the transport cost in estimate No. I, the loss per ton is reduced from Rs. 3-2 0 to rather less than Re. 1. This, on a capital of 12½ lakhs, would give an annual loss of 4 per cent.

B.—Estimates for the Anji valley area.

Following the proposed alignment for the Chenáb valley route from Jammu to Srinagar, the Anji valley is reached, at a distance of 42½ miles from Tawi, at a point about one mile west of the nearest coal outcrop in the Anji valley. From this point the colliery line would follow up the nala, for about two miles, to a point well within the coal area. Using Mr. Weightman's estimated construction rates per mile, the cost of this line would be:—

					Rs.
30	miles	at Rs.	80,000	per mile	=24,00,000
10	„	„	1,00,000	„ „	=10,00,000
2½	„	„	1,50,000	„ „	= 3,75,000
2	„	„	2,00,000	„ „	= 4,00,000
					41,75,000

The total capital expenditure on this line would therefore be, say, 42 lakhs. Using methods of calculation similar to those employed in the Ladda estimate, and allowing for a profit on ordinary local traffic of Rs. 30,000 (Mr. Weightman's estimate), the cost per ton for the transport of 50,000 tons from the Anji valley coal-field to Tawi would be Rs. 9-15-0.

ESTIMATE NO. III.

For an output of 50,000 tons per annum (Anji valley field).

Substituting the amount Rs. 9-15-0 for the transport cost per ton in Estimate No. I, the loss per ton is seen to be nearly Rs. 7. This would yield a loss of Rs. 3,50,000, which, on a capital of 46 lakhs, would give an annual loss of 7·6 per cent.

The proposed Anji valley branch of the Jammu-Kashmir railway.

The latest alignment for the Jammu–Kashmir railway passes through Talwára, a village situated on the right bank of the Chenáb River, and some two miles to the west of Riássi. Should this route be finally decided upon, it might be practicable to build a branch line connecting the Anji valley coal-field with the main line at Talwára. On the map the direct distance belween Talwára and the terminus of the branch line is 10 miles, but the total length of line necessary would probably not be less than 13 miles. Besides an expensive crossing of the Chenáb, the construction cost of a line following the Anji nala would be very heavy, not less than 2 lakhs per mile, judging from Mr. Weightman's figures for similar constructions. Should such a line be practicable it would, however, considerably lower the cost of transport of coal between the Anji valley and Tawi.

	Rs.
13 miles, at Rs. 200,000 per mile	= 26,00,000
Interest and depreciation on 26 lakhs, at 11 per cent	= 2,86,000
Carriage of 50,000 tons of coal for 55 miles, at ⅛ pie per maund per mile	= 77,344
	= 3,63,344
Cost per ton for the transport of 50,000 tons of coal from the Anji valey to Jammu . .	$=\frac{3,63,344}{50,000}$ = Rs.7-4-3

ESTIMATE NO. IV (ANJI VALLEY FIELD.)

Substituting this amount Rs.7-4-3 for the transport cost in Estimate No. III, the loss per ton is reduced from Rs.7 (nearly) to Rs.4-4. This, on a capital of 30 lakhs, would give an annual loss of 7·1 per cent.

SUMMARY OF ESTIMATES.

Locality.	Traction.	Estimated Capital.	Annual loss.
			per cent.
Ladda .	Steam	35 lakhs . .	4·8
Ladda .	Bullock	12½ „ . .	4
Anji valley .	Steam, independent line . .	46 „ . .	7·6
Anji valley .	Steam, *viâ* Anji nala, and joining the Jammu-Kashmir proposed line at Talwára .	30 „ . .	7·1

It has been estimated by Mr. Weightman that for the working of the ordinary traffic (excluding coal traffic) on the Kashmir Railway, nearly 11,000 tons of coal per annum would be required. Even with the assistance which this local market would afford, the working of the Jammu coal-fields, under the present circumstances, cannot be considered a sound commercial proposition.

XII.

SUGGESTED METHODS OF WORKING.

There can be no doubt that the working of the Ladda coal will be difficult, and will call for the highest technical skill. The reasons for this are as follows:—

(1) The high inclination of the seam.

(2) The soft and broken character of the rocks.

(3) The possibility of landslips due to the disturbance of equilibrium set up by the extraction of the coal-seam.

(4) The variability in the quality and thickness of the coal-seam.

(5) The probably heavy water discharge.

(6) The presence of fire-damp.

Under these circumstances it would be advisable, before commencing serious work, to procure the services of a skilled European mining engineer, by whom the whole of the mining operations would be laid out. By this precaution, initial mistakes, which might have serious consequences in the future, would be avoided.

In his report on the Ladda coal-field, Mr. Hope gave a description of a proposed method of working the coal. Briefly, this method is as follows:—Taking a hill-slope upon which the coal-seam outcrops, sites for main winnings would be selected 500 feet apart vertically. Each winning would consist of a pair of tunnels, 60 feet apart, rising 1 in 120, and connected for ventilation by cross-drives 100 feet apart. When these tunnels have reached their limit, a pair of roads, 250 feet back from the face of the tunnels, would be driven up on the full slope of the seam to within 100 feet of the outcrop, or the next highest winning, as the case might be. From these rise-roads pillars would

be opened out for a distance of 250 feet on either side; such pillars to be worked back in descending order. Whilst these are being worked back a new pair of rises would be put up 500 feet further back, ready for pillar working and extraction. By this means both coal and water would descend by gravity to the mouths of the main drifts.

The method of working, outlined above, is a distinctly practical and sound one. I am, however, inclined to think that it would not be advisable, from an economic point of view, to delay the working-out of each section (500 feet × limit) until the pair of roads commanding it has reached its furthest limit. In the case of the longer drives this limit might be as much as two miles, or even further. This means that at an average rate of three feet per working day, this pair of roads, for at least ten years, would produce not more than 3 tons per day, and the whole of this time the up-keep of a great length of roadway, together with the expense of a ventilating fan, would have to be provided for. It is certain that main roads driven in the coal would be very expensive, if not economically impossible to maintain. The coal itself, as has been mentioned above, is extremely friable, and pillars formed in the seam would undoubtedly speedily crumble at the edges and afford but slight support for the roads. At the same time, the roof and floor of soft shale would be another source of weakness. Taking into consideration these factors, I would recommend that the main haulage (intake) and return-air roads should be driven in the ironstone shales lying below the coal-seam. From these roads, at intervals of, say, 500 feet, pairs of cross-measure drifts would be driven, at a slight up-grade, into the coal-seam. These drifts would not be more than 50 feet in length; and from each pair an area of the coal-seam, measuring 500 feet on both strike and dip, might be entirely worked out, and the roof allowed to fall, without damaging the main roads lying securely below in the shales. At the same time the main roads would be steadily driven ahead and successive areas opened out in a similar manner. It would thus be unnecessary to leave barriers between adjacent winnings. The whole of the seam, except an outcrop barrier of 100 feet thickness, might be removed. In this way

each winning would become speedily productive, and the cost of driving the main roads and of up-keep generally, be defrayed from current revenue. The cost of driving these main tunnels should not exceed eight rupees per foot, and this, allowing for the expense of the driving of the ventilation-holings and the cross-measure drifts, would be a constant charge on the coal of about 7 annas per ton, presuming that the average thickness of the seam is 2½ feet.

In Europe, highly inclined and contorted coal-seams are, as a rule, worked on the longwall system. In this method of working no coal pillars are formed and left for subsequent extraction, the whole of the coal being removed in a continuous face, at one working. The roads are maintained through the " waste" or "gob" by means of pack-walls built of stone obtained from the bands of stone in the coal-seam or from the ripping of the roof in the roads. In some cases stone for packing and filling the waste is taken down from the surface.

I am of the opinion that this method of working might be successfully adopted in the Ladda coal-field. The chief difficulties would lie in the varying thickness of the seam and the scarcity of packing material. The roads would undoubtedly be difficult to maintain in those places where the seam is thick. Both methods might easily be tried in different areas, and the most successful method adopted generally. It is probable that where the seam is thin, longwall working would be advantageous.

Ventilation and lighting.

The question of ventilation is a most important one, especially so considering that fire-damp is given off from the coal. It will be absolutely necessary to maintain throughout the workings a current of air sufficient—in the words of the English Coal Mines Act—to dilute and render harmless noxious gases to such an extent that the working places and travelling roads of the mine may be safe for persons working and travelling therein. To effect this, artificial, as opposed to natural, ventilation will be necessary. Each main winning will therefore require to be ventilated by means of a fan—preferably of the Capell or Schiele type—driven either by a steam engine, or by Pelton wheels, or turbines. Ample power to drive the latter could be obtained

by damming one or more of the numerous mountain streams in the neighbourhood.

In regard to lighting, the presence of fire-damp will render imperative the use of safety lamps throughout the workings. In the hands of the natives some simple type of lamp, such as those of the Marsaut pattern, would probably give the best results.

APPENDIX.

NOTE BY MR. E. L. HOPE ON THE JAMMU COAL-FIELDS.

On this my second visit to the coal-fields I was associated with Messrs. Oldham and Simpson, of the Geological Survey of India, the idea being, I understand, that, having had previous experience in the working of highly inclined coal-seams in India, I should advise further as to the best method of working the coal.

2. I arrived at Jammu on the 23rd March 1903, and, meeting Mr. Simpson between Assan and Thalwal on the 28th idem, accompanied him along the coal outcrop as far as Bakl on the Chenab.

From there we returned to meet the Resident in Kashmir at Mootal on the 12th April, being also in company with Mr. Oldham during the latter part of the tour.

I then retraced my steps alone as far as Assan to fix sites for trial headings, eventually leaving the coal-field on the 18th April.

3. This further examination of the outcrop has confirmed the opinion expressed in my note, dated 9th December 1902, that a large area of coal exists, but as the further trials of the coal and the exploratory headings recommended in my first note have not yet been pushed on with, I have very little to add to the remarks *re* the value of the field and the opening out of workings made in paragraph 4 of the same.

4. It seems quite clear, however, from the behaviour of such drifts as have been driven, that if coal-working on a large scale is to be undertaken, it will be practically impossible to maintain the main roads of the mines in the coal-seam itself. Driving in some firmer strata at a distance from the coal and its soft shales, and cross-cutting over to the seam at intervals as required will be imperative.

The ferruginous shales about 20 to 50 feet below the seam should form a good medium in which to drive main intake and return air roads. The expense to be incurred in the first instance would, in my opinion, be more than recouped in the reduced cost of maintenance and the lighter timbering required.

In discussing this matter with Mr. Simpson he pointed out that if such roads were driven, they would, being below the coal, be practically uninfluenced by the subsidence of roof which would occur during the process of extraction of the coal itself, and this being so, such extraction could be taken in hand as soon as the circumstances of the seam admitted of it, instead of waiting until the main roads of any individual set of workings had reached their limit, and then working the coal back, as I had originally suggested.

With this view I quite agree: the advantages are so obvious as to need no discussion.

5. The exploratory headings referred to in paragraph 3 above should now be pushed on with.

Sites have been selected as follows :—

(*a*) At Hakroli, under the lands of Assan village ; the outcrop is visible in the bed of the Anji stream, but to ensure safety from floods, the site for the mouth has been fixed higher up the hillside where excavations to find the coal horizon are already in progress.

(*b*) At Satrani Kund, about half way (vertically) between Sukhal gully pass and the Anji stream. The direction of dip of the strata here is about N. 42° E., but the drift has been set off to go at N. 68° E., so as to keep it as far as possible in firm ground. Probably about 100 feet dead work may have to be driven before the coal horizon can be struck. When coal is found it should, of course, be followed along the strike of the measures.

(*c*) At Jungle, below the Jungle drive, at the point originally proposed in my first note.

This drift will also have to pass through some loose ground owing to a surface slip, but it is not expected that the latter will prove of any great extent.

Possibly in none of the above headings will any ventilation, other than what can be set up by means of rotary hand fans, be required. It is understood that Mr. Godwin will arrange for the necessary plant, whereby the cost of secondary headings will be saved.

6. In my first note I recommended short drifts to be put in about 1,000 feet apart on the hillside between the Anji stream and Sukhal gully. Excavations for these have been started, but the surface soil is so loose that it is doubtful whether they can be put in without considerable expense. I think, therefore, they might be abandoned for the present.

I also consider that, as the continuity of the seam over a fairly large area is more or less proved, no more minor explorations are required at present, with the exception of a small drift at Nadla, near Assan, and the excavations to find the coal horizon about 500 feet above the Anji stream at Thalwal, at both of which places it would be advantageous to prove the existence of the coal, could this be done without much expenditure.

Drift "Baoli No. 3," which has just struck good coal, might also go on a few feet further.

What is urgently required now is to test the behaviour of the seam, *i.e.*, to ascertain to what extent it thickens and thins, and whether this irregularity will militate against its successful working. Valuable information in this respect should be obtainable from the three main exploratory headings at Hakroli, Satrani Kund, and Jungle, of which carefully recorded sections should be maintained.

G. I. C. P. No. 323 D. G. Survey.—24-8-04.—J. Marum.

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CONTENTS.

PART I.

RECENT ARTESIAN EXPERIMENTS IN INDIA, *by* E. VREDENBURG, A.R.C.S., *Officiating Deputy Superintendent, Geological Survey of India.*

Pages

CHAPTER I.

General consideration . . . . . 1—24

CHAPTER II.

DETAILED ACCOUNTS OF SOME RECENT EXPERIMENTS.

1. Baluchistan . . . . . 24—28
2. The Gangetic alluvium . . . . . 28—49
3. Other alluvial areas . . . . . 49—69
4. Gujárát . . . . . 69—75
5. Borings in other tertiary rocks 75
6. The Gondwanas . . . . . 76—82
7. The Vindhyans . . . . . 82—83
8. The Deccan Trap . . . . . 83—87
9. Other rocks . . . . . 87—88
10. Conclusion 88

PART II.

REPORT ON THE RAMPUR COAL-FIELD, *by* G. F. READER, *Mining Specialist, Geological Survey of India.*

Pages

CHAPTER I.

Introduction . . . . . 89—93

CHAPTER II.

Geology . . . . . 93—101

CHAPTER III.

Coal explorations . . . . . 101—112

CHAPTER IV.

Workable thickness of coal proved . . . . . 112—116

Appendix . . . . . 117—124

PART III.

NOTES ON THE "EXOTIC BLOCKS" OF MALA JOHAR IN THE BHOT MAHALS OF KUMAON, *by* A. VON KRAFFT, PH.D., *Assistant Superintendent, Geological Survey of India.*

	Pages
I.—Introduction	127—132
II.—Stratigraphical features	132—135
III.—General characters of the igneous rocks and exotic blocks	135—150
IV.—Detailed description of the area—	
(*a*) The neighbourhood of Balchdhura Pass	151—154
(*b*) The Kiogarh High Plateau	155
1.—The Flysch	155—158
2.—The volcanics and exotic blocks	158—162
(*a*) The area south of Kiogarh Plateau—	
1.—Structural features	162—165
2.—The exotic blocks	166—169
V.—Results	169—184
Index to Plates	185—186
Illustrations	187—188

PART IV.

REPORT ON THE JAMMU COAL-FIELD, *by* R. R. SIMPSON, B.SC., *Mining Specialist, Geological Survey of India.*

	Pages
I.—Introduction—	
The principal coal consumers in North-Western India. Fuel equivalents. Importance of the exploitation of local coal-fields. Relation of the proposed Kashmir railway to the coal question.	189—190
II.—Position and physical features of the coal-field	191—192
III.—Previous observers—	
Mr. H. B. Medlicott, Mr. T. D. La Touche, Mr. J. Godwin, Mr. A. Mert, Mr. Osterloh, Mr. E. L. Hope.	192—193

Page

IV.—Origin of the present enquiry—
Conference of Messrs. R. D. Oldham, E. L. Hope., and the Writer. Acknowledgment of assistance. Topographical map . . . . . 193—194

V.—Geology of the Ladda field—
Age of formations. Folding. Generalised section. Details of the coal-bearing formation—Doodar ravine—Jungle ravine—Jungle gully to Sukhál gully—Anji valley—Between the Anji and Chenáb valleys—Between Mootal and Sandráni. . . 194—210

VI.—Geology of the Sangar Marg field—
Geology. Details of the coal-bearing formation—Between the Chenáb River and Sangar Marg—The Ikni-Sujánpur slope—The Sujánpur Synclinal—The Bugoola Synclinal . . 210—216

VII.—The Mehowgala, Siró valley, and Kálakót fields—
The Mehowgala field—The Siró valley field—The Kálakót field. . . . . 216—222

VIII.—The Lodhra field—
Physical and Geological features. Details of the coal-bearing formation—The Lodhra and Madiál nalas—The Thansu and Kolri nalas. . . . . 222—225

IX.—Nature and quality of the coal—
Physical characters. Chemical composition and calorific value. Burning tests—Jammu water-works—Locomotives on North-Western Railway. Briquetting. Washing. Coking . . 225—244

X.—Workable areas and quantity of fuel available—
Results of the long drives in the Ladda field. Division of the coal areas—The Ladda and Sangar Marg coal-fields—The Mehowgala field—The Siró valley field—The Kálakót field—The Lodhra field. . . . . 244—252

XI.—Economic aspects of the coal question—
Market value of Ladda coal. Most favourable position for a colliery. Probable output of coal. Estimates for the Ladda slope area—Estimate No. I—Bullock traction—Estimate No. II. Estimates for the Anji valley area—Estimate No. III—The proposed Anji valley branch of the Jammu-Kashmir Railway—Estimate No. IV. Summary of Estimates . . 252—258

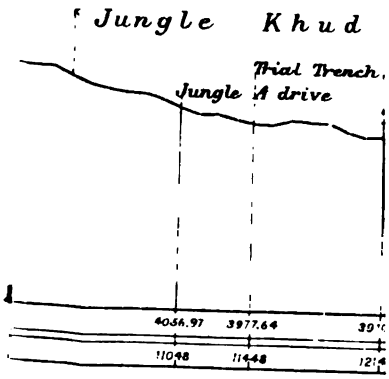
XII.—Suggested methods of working—

Appendix . . . . . 258—261

Note by Mr. E. L. Hope . . . . . 262—263

DIA

Pl. 4.



LADDA COALFIELD

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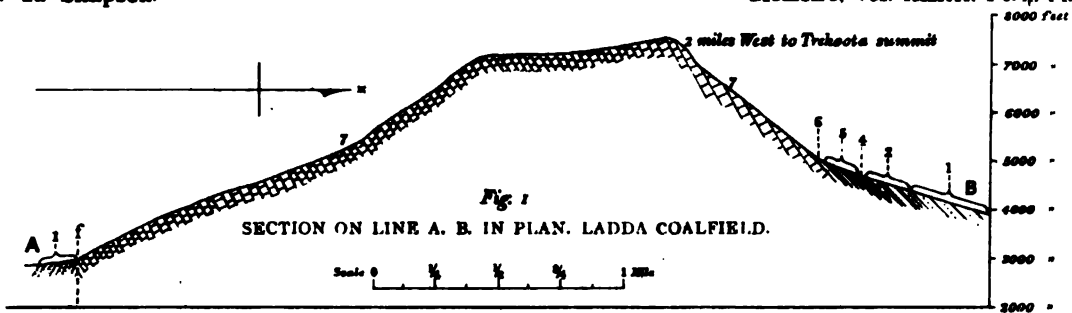


Fig. 1

SECTION ON LINE A. B. IN PLAN. LADDA COALFIELD.

1 Grey Sandstones & red clays. (Murree)
2 Olive Shales with nummulitic limestone
3 Coal Seam ..... } (Subathu)
4 Ironstone shales ..... }
5 Shales
6 Siliceous grit
7 Great Limestone
f Fault

SECTION ON LINE C. D. IN PLAN. LADDA COALFIELD.

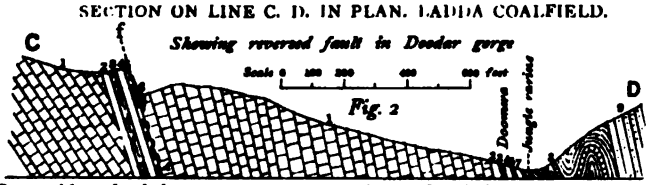


Fig. 2

6 Coal Seam with coaly shales
5 Shales
4 Ironstone
3 Ironstone shales
2 Ironstone
1 Great Limestone
f. Faults
A Lain Drive
9 Grey sandstones & red clays
8 Olive shales & nummulitic limestone
7 Limestone debris
5 Grey-black clay with coal pipes & limestone bands
4 Ironstone
3 Ironstone shales
2 Ironstone
1 Great Limestone

SECTION ON LINE E. F. IN PLAN. LODHRA COALFIELD, JAMMU

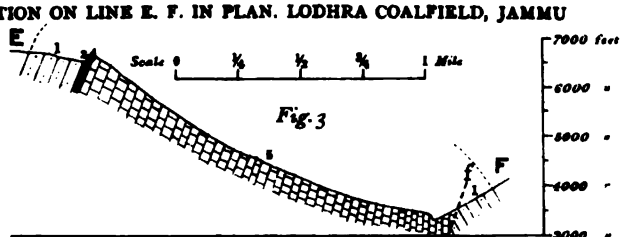


Fig. 3

1 Grey sandstones & red clays. (Murree)
2 Olive shales & nummulitic limestone
3 Coal ..... } (Subathu)
4 Ironstone shales ..... }
5 Great Limestone ..... (Pre-tertiary)
f Fault

SECTIONS OF THE LADDA AND LODHRA COALFIELDS.

PLATE 5.

PHOTOGRAPHED BY R. D. OLDHAM.

1. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Sub áthu).
3. Blue-grey limestone (pre-Tertiary).

Bemrose, Collo., Derby.

JUNGLE RAVINE, LADDA COALFIELD, JAMMU.

PLATE 6.

PHOTOGRAPHED BY R. D. OLDHAM.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
1. Blue-grey limestone (pre-Tertiary).

THE ANJI VALLEY, LADDA COALFIELD, JAMMU.

Bemrose, Collo., Derby.

PLATE 7.

1. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
3. Blue-grey limestone (pre-Tertiary).

R. R. Simpson.

Memoirs, Vol. XXXII. Pt. 4, Pl. 7.

Fig. 1.

Fig. 2.

Bemrose, Collo., Derby.

THE APPROACH TO THE LODHRA COALFIELD, JAMMU.

PLATE 8.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Sub áthu).
1. Blue-grey limestone (pre-Tertiary).

A. The Bugoola synclinal.
B. The main anticlinal.
C. The Sarodabar outlier.

Bemrose, Collo., Derby, Eng.

THE EASTERN PORTION OF THE SANGAR MARG COALFIELD, JAMMU.

PLATE 9.

3. Grey sandstones and red clays (Murree).
2. Nummulitic limestone, shales, and coal seams (Subáthu).
1. Blue-grey limestone (pre-Tertiary).

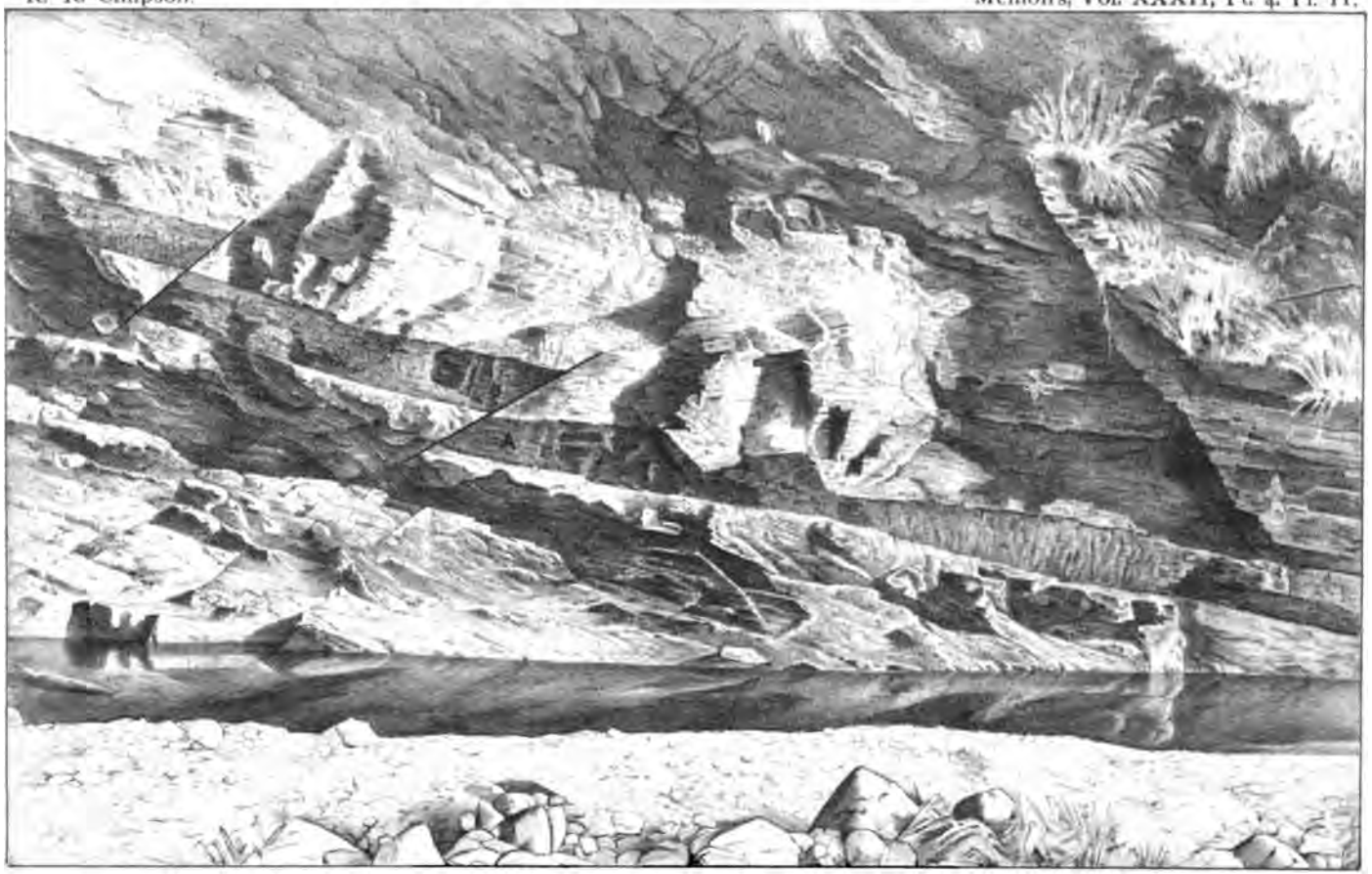
E. Drives E. and F.
J. Jungle drive.

Benrose, Collo., Derby, Eng.

JUNGLE RAVINE, LADDA COALFIELD, JAMMU.

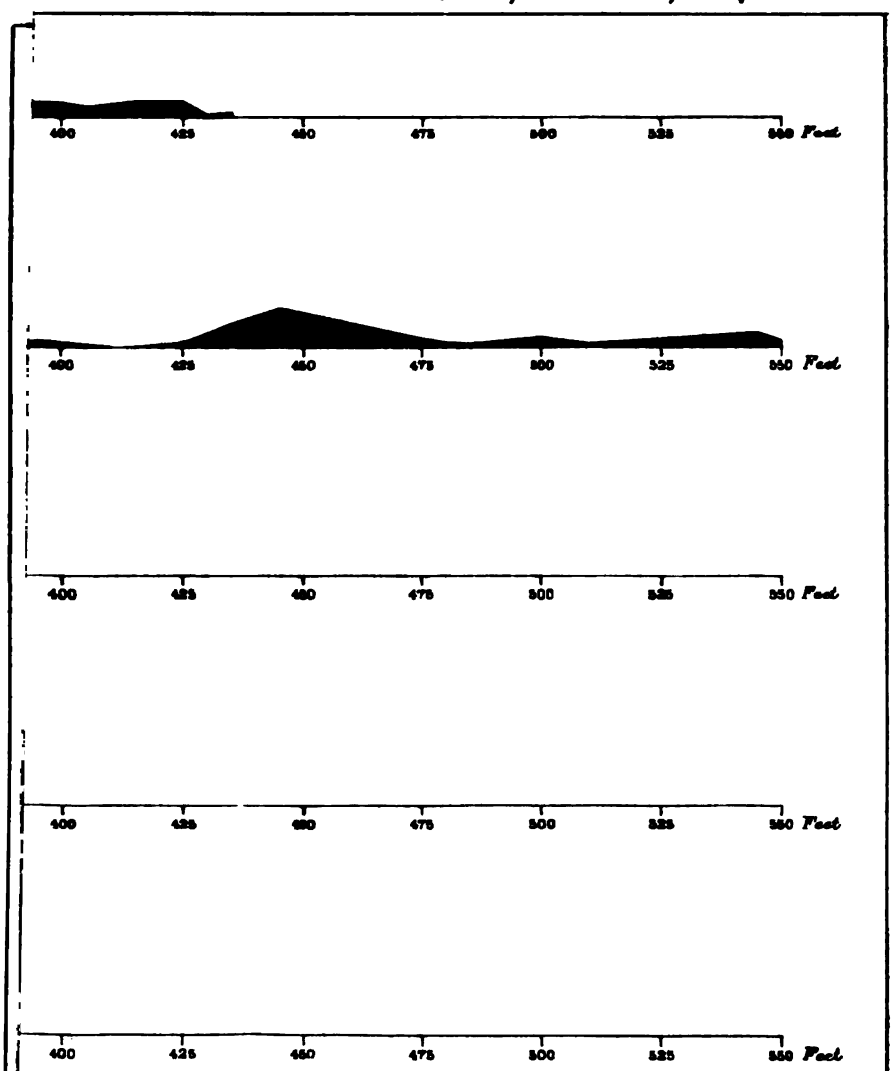
Bemrose, Collo., Derby, Engr.

SHAFT-SINKING, SIRÓ VALLEY COALFIELD, JAMMU.



FAULTING IN THE SIRÓ VALLEY COALFIELD.

A. Coal Seam 22 Inches Thick.



DDA COALFIELD.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab, Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The re-soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain ; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *vid* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills, (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan (with a map). Report of a Journey through India in the winter of 1888-89, by Dr. Johannes Walther, translated from the German, by R. Bruce Foote. On the Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills (with 3 plans). Further Note on Indian Steatite. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt-Marl (with five plates). On veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sheráni country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of

the Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle) Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* DR. P. MARTIN DUNCAN. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on rocks from the Salt-range, Punjab (with two plates).

VOL. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Sub-recent *and* Recent Deposits *of the valley plains of* Quetta, Pishin, and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

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VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

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VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of petroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landslip, Garhwal (with 5 plates and 2 maps).

Part 3.—*On the* Cambrian Formation *of the* Eastern Salt-range (with a plate). The Giridih (Karharbari) Coal-field, *with notes on the* labour and methods of working (with 2 maps and 8 plates of sections). *On the* Occurrence of Chipped (?) Flints *in the* Upper Miocene of Burma (with a plate). Note *on the* Occurrence *of* Velates Schmideliana, Chemn., *and* Provelates grandis, Sow. *Sp. in the* Tertiary Formation *of* India *and* Burma (with 2 plates).

Part 4.—*Note on the* Geology of Wuntho *in* Upper Burma (with a map). Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán. *On* Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal. On a Mica-Hypersthene-Hornblende-Peridotite *in Bengal.*

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry. Some* early allusions *to* Barren Island: *with a few remarks thereon.* Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks.*

Part 2.—*On the importance of* Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times. *Report on the Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. The development and Subdivision of the Tertiary system in Burma.*

Part 3.—*On the* Jadeite *and other rocks, from* Tammaw *in* Upper Burma. *On the* Geology *of the* Tochi Valley. *On the* existence *of* Lower Gondwanas *in* Argentina.

Part 4.—*On the* Igneous Rocks *of the* Giridih (Kurhurbaree) Coal-field *and their* Contact Effects. *On* some outliers *of the* Vindhyan system south *of the* Sone and their relation *to the* so-called Lower Vindhyans. *Notes on a* portion *of the* Lower Vindhyan area *of the* Sone Valley. *Note on* Dr. Fritz Noetling's paper *on the Tertiary system in Burma, in the Records of the Geological Survey of India for 1895, Part 2.*

Vol. XXIX, 1896.

Part 1.—Annual report for 1895. *On the Acicular inclusions in Indian Garnets. On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks* (with 1 plate).

Part 2.—*Notes on the* Ultra-basic rocks *and* derived minerals *of the* Chalk (Magnesite) hills, *and other localities near* Salem, Madras (with 2—6 plates). *Preliminary notes on some* Corundum localities *in the* Salem and Coimbatore districts, Madras (with 7—9 plates). *On the occurrence of* Corundum *and* Kyanite *in the* Manbhum district, Bengal. *On the papers by* Dr. Kossmat and Dr. Kurtz, *and on the ancient Geography of "Gondwanaland." Notes from the Geological Survey of India.*

Part 3.—*On some* Igneous Rocks *from the* Tochi Valley. *Notes from the Geological Survey of India.*

Part 4.—Report *on the* Steatite mines, Minbu District, Burma. Further notes *on the* Lower Vindhyan (Sub-Kaimur) area *of the* Sone Valley, Rewah. *Notes from the Geological Survey of India.*

Vol. XXX, 1897.

Part 1.—Annual report for 1896. *On* some Norite *and* associated Basic Dykes *and* Lava-flows *in* Southern India (with plates I to II). *The reference of the genus* Vertebraria. *On a* Plant of Glossopteris with part of the rhizome attached, *and on the* structure of Vertebraria (with plates III to V).

Part 2.—The Cretaceous Deposits of Pondicherri (with plates VI to X). *Notes from the Geological Survey of India.*

Part 3.—Note on Flow-structure in an Igneous dyke (with plate XI). Additional note on the Olivine-norite dykes at Coonoor (with plate XII). Report on some trial excavations for corundum near Palakod, Salem District (with plate XIII). Report on the occurrence of coal at Palana village in Bikanir State (with plate XIV). An account of the geological specimens collected by the Afghan-Baluch Boundary Commission of 1896 (with plate XV). *Note from the Geological Survey of India* (with plates XVI and XVII).

Part 4.—On Nemalite from Afghanistan. On a quartz-barytes rock occurring in the Salem District, Madras Presidency (with plate XVIII). Note on a worn femur of Hippopotamus irravadicus, Caut. and Falc., from the Lower Pliocena of Burma (with plates XIX and XX). On the supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. *Notes from the Geological Survey of India.*

Vol. XXXI, 1904.

Part 1.—Prefatory Notice. On a deposit of copper ore near Komai, Darjeeling District. Note on the Zewan beds in the Vihi District, Kashmir. Report on the coal deposits of Isa Khel, Mianwali District, Punjab. Report on the Um-Rileng Coal-beds, Assam. Note on a sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.

Part 2.—Lt.-Genl. C. A. McMahon, F.R.S. Note on Cyclolobus Haydeni, Diener. The Auriferous occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at the East Indian Railway Collieries, with a supplementary note by the Director, Geological Survey of India. Miscellaneous Notes.

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